MARCH, 1958

modern castings

The Foundrymen's Own Magazine

future meetings and exhibits

MARCH

Feb. 28-March 1 . . American Society for Quality Control, *Middle Atlantic Conference.* Hotel Statler, New York.

2-6 . . American Society of Mechanical Engineers, *International Gas Turbine Power Division Conference & Exhibit.* Shoreham Hotel, Washington, D. C.

3-7 . . Spectroscopy Society, *Conference on Analytical Chemistry & Applied Spectroscopy.* Penn-Sheraton Hotel, Pittsburgh, Pa.

11-13 . . Instrument Society of America, Pittsburgh Section, *Conference on Instrumentation for Iron and Steel Industry.* Hotel Roosevelt, Pittsburgh, Pa.

12-13 . . Foundry Educational Foundation, *College-Industry Conference.* Statler Hotel, Cleveland.

17-18 . . Steel Founders' Society of America, *Annual Meeting.* Drake Hotel, Chicago.

17-21 . . National Association of Corrosion Engineers, *Conference & Exhibition.* Civic Auditorium, San Francisco.

25 . . Metallurgical Associates, Inc., *Sales Clinic.* Hotel Carter, Cleveland.

APRIL

14-16 . . American Institute of Mining, Metallurgical & Petroleum Engineers, *41st National Open Hearth Steel Conference.* Statler Hotel, Cleveland.

14-17 . . American Society of Mechanical Engineers, *Design Engineering Conference.* International Amphitheatre, Chicago.

14-18 . . American Welding Society, *Annual Meeting and 6th Welding Show.* Kiel Auditorium and Statler Hotel, St. Louis.

21-23 . . Association of Iron and Steel Engineers, *Spring Conference.* Dinkler-Tutwiler Hotel, Birmingham, Ala.

27-May 1 . . American Ceramic Society, *Annual Meeting.* Penn-Sheraton Hotel, Pittsburgh, Pa.

MAY

1-8 . . American Society of Tool Engineers, *26th Annual Meeting & Convention.* Convention Center, Philadelphia.

Continued on page 2

Future meetings

Continued from Inside Front Cover

8-10 . . American Material Handling Society, *Western Material Handling Show.* Great Western Exhibit Center, Los Angeles.

9-10 . . Malleable Founders' Society, *Market Development Conference.* Edgewater Beach Hotel, Chicago.

12-16 . . American Society For Metals, *1st Southwestern Metal Congress & Exposition.* State Fair Park, Dallas, Texas.

19-20 . . Non-Ferrous Founders' Society, *Annual Meeting.* Carter Hotel, Cleveland.

19-23 . . American Foundrymen's Society, *62d Annual Castings Congress & Foundry Show.* Public Auditorium, Cleveland.

21-22 . . American Iron & Steel Institute, *Annual Meeting.* Waldorf-Astoria Hotel, New York.

JUNE

9-10 . . Malleable Founders' Society, *Annual Meeting.* The Homestead, Hot Springs, Virginia.

9-12 . . American Society of Mechanical Engineers, *National Materials Handling Conference.* Public Auditorium, Cleveland. *Held in conjunction with Materials Handling Exposition.*

12-13 . . AFS 15th *Annual Chapter Officers Conference.* Hotel Sherman, Chicago.

19-21 . . AFS 3d *Annual Foundry Instructors Seminar.* Case Institute of Technology, Cleveland.

February Cover Illustration was from Famed Collection

■ The cover photograph for the February issue of MODERN CASTINGS was from a collection of dramatic views of British industry taken by Walter Nurnberg, F.I.B.P., F.R.P.S., and published in a volume entitled, *"Men and Machines."*

Mr. Nurnberg's photograph used for the February issue showed the preparation of a large and intricate mold in the iron foundry of George Fletcher & Co., Ltd., Derby, England.

The forward to *"Men and Machines"* states that, "The story of industry is a story of people, not merely one of plant and machinery. It tells of that perfection of motion which only comes from long experience. It tells of skill and achievement; it tells of that dignity which only accepted responsibility can engrave upon the face of Man.

"These are the themes which this collection of photographs illustrates."

march, 1958
vol. 33, no. 3

modern castings

in this issue

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Modern Castings is indexed by Engineering Index, Inc., 29 West 39th St., New York 18, N. Y. and microfilmed by University Microfilms, 313 N. First St., Ann Arbor, Mich.
The American Foundrymen's Society is not responsible for statements or opinions advanced by authors of papers or articles printed in its publication.
Published monthly by the American Foundrymen's Society, Inc., Golf & Wolf Roads, Des Plaines, Ill. Subscription price in the U.S., $5.00 per year; elsewhere, $7.50. Single Copies 50c. April, May and June issues $1.00. Entered as second-class mail at Pontiac, Illinois. Additional entry at Des Plaines, Ill.

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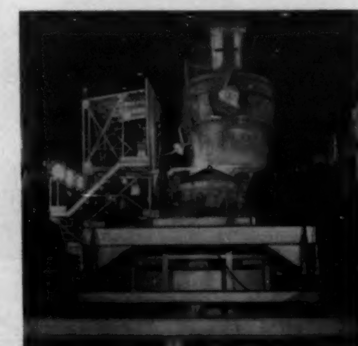
VACUUM STREAM DEGASSING

Our Modern Casting's cover this month pictures a relatively new technological development in the metal casting industry—vacuum stream degassing of steel. Like shell molding and the CO_2 process, this new technique has come to us from Germany. In 1950 experiments were initiated at the Bochumer Verein Steel Works to produce hydrogen-free ingots weighing up to 150 tons. Low hydrogen steel was needed to eliminate a serious defect known as "flaking" encountered in forging operations. The most practical solution to removing hydrogen from so large a quantity of steel proved to be stream-droplet degassing.

Briefly, the process involves: (1) An empty ladle is placed in a vacuum chamber which is pumped down to a pressure level of 200 microns—20 mm. (2) Conventionally melted and killed steel is tapped into a bottom-pour ladle. (3) Pouring nozzle of ladle is positioned within an airtight gasket on top of the vacuum chamber. (4) Stopper rod is raised so molten steel impinges on an aluminum diaphragm which melts, permitting steel to enter vacuum chamber. (5) The nearly instantaneous pressure drop causes the molten metal to burst spectacularly into a spray of finely divided molten particles.

Because of the large surface area exposed to the vacuum, degassing proceeds so rapidly that relatively high pouring rates are possible—6 to 10 tons a minute. At this pouring rate the temperature drop of the steel is about 100 F. Hydrogen content can be reduced from 6 ppm down to 3 ppm. At the same time considerable quantities of oxygen and nitrogen are removed from the steel. When transfer is completed, the ladle of degassed steel is removed from the vacuum chamber and castings or ingots poured. Careful pouring to avoid turbulence will hold hydrogen pickup to a negligible level.

Virtual elimination of flaking problems and micro shrinkage, freedom from nonmetallic inclusions, superior fatigue life and improved ductility are the plus factors loading to the increased demands for hydrogen-free steel in the manufacture of inductor shafts, turbine rotors, high-pressure casings, barrel shafts, rolls, dies, and high-temperature bearings. Pictured above is a U. S. Steel Corp. installation recently completed in this country. General Electric Co. is also treating steel by this process; and more installations are under way. Recently a 250-ton alloy steel ingot was poured from stream-degassed steel—the largest piece of vacuum-refined metal ever produced in the world.



Urge Full Use of Market by New England Foundries

by H. F. TAYLOR / *Professor*
Foundry Metallurgy
Massachusetts Institute of Technology
and HAROLD BROWN / *Sales Manager*
Hunt-Spiller Mfg. Co.
Boston, Mass.

■ With current consumption of castings far exceeding the local supply; the growing development of electronics, aircraft, and guided missiles industries; and the influx and development of industry in excess of that moving to other areas; the future of the New England foundry industry looks bright indeed. However, future prosperity depends not so much upon fate, chance, or the economic situation, as upon New England foundrymen themselves.

Market Unrealized

In general, the closer the customer is to the foundry, the better the liaison, and, consequently, opportunity for business. Still, foundries from as far outside the New England area as Ohio, Wisconsin, and Virginia are providing castings for New England customers. Four manufacturers within a 40 mile radius of Boston buy a total of three million dollars worth of castings a year *outside* the New England area.

Organization Needed

Dun and Bradstreet reports that over 50 per cent of business failures stem from faulty organization. Modern equipment and a healthy market are not enough to send sales and profits up. It also takes an *organization;* the men who have the responsibility for managing, administering, and planning company course of action must be capable of exploiting the market to the greatest possible benefit for the company. The foundry industry is no different.

Modernization

The only way to stay in business today is to increase productivity. If the production line is modernized with better equipment, production schedules, and standards of quality control, the result should be a better product at a cheaper price—in short, a more competitive organization.

The customer will not "beat a path" to the foundry door. Old-fashioned salesmanship can not be underestimated as a means of ferreting out customers within existing markets and explaining fully and accurately just what our castings can do for them.

■ Condensed from a talk presented before the New England Regional Conference at the Massachusetts Institute of Technology in October, 1957.

Conversion to Hot-Blast Helps German Foundry

■ Economy of operation and improved quality have resulted from conversion of two cold-blast cupolas to hot-blast operation at the Leipzig Iron and Steel Works, Leipzig, Germany. Installation and operation of the hot-blast cupolas are described in "Operation Experiences with Hot-Blast Cupolas," by R. Drechsler, *Giessereitechnik*, No. 1, 1956.

Installation

In inaugurating the change-over from cold-blast to hot-blast operation, there was no fundamental change in design of the melting units; a second row of tuyeres was retained. The charging doors, however, previously open, were fitted with sliding doors and counter weights so that they could be closed after each charge to avoid dilution of top gas. A smoke stack with a top gas damper was installed over each cupola.

The recuperator, located in a combustion chamber, consists of 96 pipes, each 6-½ ft long, arranged in three sets of 32. Only eight of these pipes need be renewed because of wear.

Operation

By introducing preheated secondary air with a closed charging door, combustion of the CO-containing top gas occurs spontaneously or by pilot flame. A temperature of 1290-1650 F is reached in the combustion chamber. Gases descend through recuperator (pipe system) and give up their heat to the pipes. Gases leave the pipe system at 485-570 F. Fresh air flows through pipes counter-current, with a rise in temperature to 750-840 F.

Before each shift, the recuperator pipes are blown out with compressed air to free them from dust which could effect heat exchange. The recuperator system may be pre-heated shortly before melting if there is another source of gas besides top gas, so that hot-blast is available at the beginning of melting.

The hot-blast cupola has up to 35 per cent higher melting rate over cold-blast, with a 30 per cent saving in coke consumption. The temperature of iron at tap is about 72F higher.

An improvement in sulfur content has been established, and the volume of slag is about 35 per cent lower than in cold-blast furnaces. The more limited lining wear in the melting zone saved up to 20 per cent of the refractory lining material.

■ Condensed from a translation by H. Brutcher; circle No. A, Page 7-8, for a list of Brutcher Translations available for purchase.

Build an idea file for plant improvements. The post-free cards on page 7-8 will bring more information on these new . . .

products and processes

CORE PASTES . . . in plastic squeeze applicator eliminates filling of putty tubes.

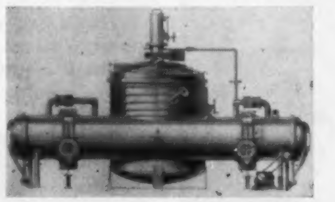
Request free sample by circling No. 401 on Reader Service Card, Page 7-8 *Frederic B. Stevens, Inc.*

For Manufacturer's Information Circle No. 401, Page 7-8

CO_2 SAND MIXER . . . said to cut mixing time in half. Works equally well with all core binders; will not heat, crush or ball sand. Portable or fixed, unit is easily cleaned. Core sand mixer is one of lowest priced in industry, according to the manufacturer. Model illustrated has 2 cu ft capacity, mixing over 100 lb core sand per load. *U. S. Forge & Foundry Co.*

For Manufacturer's Information Circle No. 402, Page 7-8

MELTING AND CASTING FURNACE . . . vacuum induction type, features mold tunnel for direct casting of shapes or ingots under vacuum or inert gas atmosphere. Four chamber furnace does not require break-



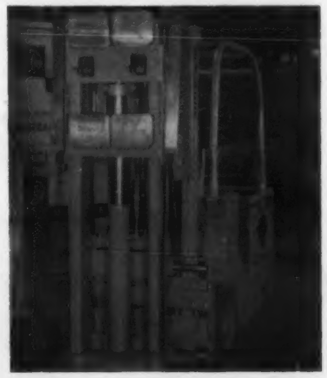
ing vacuum in main chamber for inserting or removing molds. Automatic conveyor moves mold from entrance lock into mold tunnel, and into exit lock where casting is cooled before exposure to atmosphere. Continuous casting. Special modifications available. Capacity range 300-5000 lb of steel. *Kinney Mfg. Div., New York Air Brake Co.*

For Manufacturer's Information Circle No. 403, Page 7-8

INFRARED HEATING ELEMENTS . . . said to provide infrared wave length best suited for heating, baking, and drying; peak infrared emmission developed at 2.3 microns. Manufacturer claims practically no loss of energy through production of visible light. Permits flexibility as power input and radiation can be matched to speed of conveyors handling sand, cores, and castings. *Quartz Products Corp.*

For Manufacturer's Information Circle No. 404, Page 7-8

MULTI-PURPOSE ATTACHMENT . . . for fork lift trucks designed to handle varied-sized cartons without time-consuming changing of attach-



ments. Includes side shifter, lift extender, carton lip, finger lift, and hinged forks. Said to pick up, haul, and unload regardless of shape or size of load. Maximum capacity, 1000 lb. *Baker-Raulang Co.*

For Manufacturer's Information Circle No. 405, Page 7-8

SHELL MOLDING RELEASE AGENT . . . a non-flammable silicone emulsion, resists excessive film build up and repeated freezing and thawing cycles. Said to be undamaged by storage at 125 F. Shipped as concentrate; dilute with water in your plant. Sludge formation on pattern surface claimed to be practically eliminated. *Silicones Div., Union Carbide Corp.*

For Manufacturer's Information Circle No. 406, Page 7-8

SAW BAND . . . employs positive rake angle said to increase cutting efficiency. Forward slanting tooth face evolves into smooth, elliptical gullet claimed to give best distribution of stresses. Hooked teeth said to result

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■ **Details on these products and processes are available to MODERN CASTINGS readers. See page 7-8.**

in faster cutting rates with less effort, and penetrate easily with less feed pressure.

Hard edge, disposable carbon steel saw bands are said to be best suited for ferrous metals and many nonferrous materials where rapid chip production demands ample gullet capacity.

High speed saw bands said to be capable of speeds considerably higher than permitted with carbon steel blades, retaining their hardness at 1100 F. Higher band tensions can be used because of increased tensile strength of the back of the band; this is said to increase straightness of cutting. Band saw said to be suited for stainless steel alloys and hard machining materials such as titanium alloys. *DoAll Co.*

For Manufacturer's Information Circle No. 407, Page 7-8

CASTING EPOXY . . . developed especially for making core driers for use in dielectric ovens. Said to eliminate need for expensive driers; easy to cast. *Houghton Laboratories.*

For Manufacturer's Information Circle No. 408, Page 7-8

ROLLOVER AND DRAW . . . machine said to eliminate use of overhead crane for medium and large size molding or coremaking operations. Machine features 30 sec automatic operating cycle with full 30 in. draw. Clamps boxes or molds 15-69 in. deep, up to 60 in. widths, without machine adjustments. Capacities to 10,000 lb. *Beardsley & Piper Div., Pettibone Mulliken Corp.*

For Manufacturer's Information Circle No. 409, Page 7-8

CORE BLOWER . . . said to provide versatility and speed with sleeve-type stationary magazine and slot design to operate with all core sand mixes. Blows or shoots cores weighing ounces to 10 lb. Features quick change blow plate and shoot heads said to be interchangeable in seconds without use of wrenches. Machine will not operate unless core box properly located, manufacturer claims. *Demmler Mfg. Co.*

For Manufacturer's Information Circle No. 410, Page 7-8

CORE SAND BLENDER . . . said to offer advantages in sand conditioning by pre-mixing bonds with shakeout sands before moisture addition reduces flowability. Useful in

Circle No. 546, Page 7-8 ➧

obtaining random distribution of grain sizes where this is a problem. Requires no elevator feed, mounted on conveyor belt, ready to use in less than 25 man-hours, manufacturer claims. *Pekay Machine & Engineering Co.*

For Manufacturer's Information Circle No. 411, Page 7-8

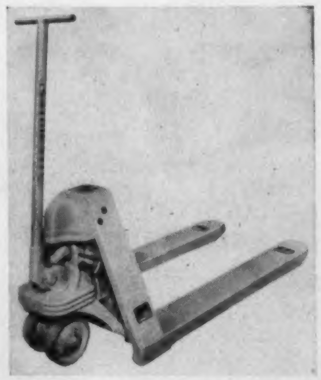
CHEMICAL JOINING . . . of non-ferrous metals made by permanent chemical bond through ion exchange. New material is said to reduce present joining costs 50-300 per cent. May be used in manual or mechanized operations. *Intertectics, Inc.*

For Manufacturer's Information Circle No. 412, Page 7-8

RADIATION PYROMETER . . . gives 98 per cent of full reading in two seconds. Special unit for moving objects gives reading in 0.6 sec. Measures radiant energy given off by hot objects. Can be used at greater distance from hot objects than possible with other types. Models cover temperatures 1000 to 3300 F. Accessory equipment is adaptable to furnace and salt bath installations. *Instrument Div., Robertshaw-Fulton Controls Co.*

For Manufacturer's Information Circle No. 413, Page 7-8

HAND LIFT TRUCKS . . . non-motorized, mechanical or hydraulic operated for safe lifting of weights up to 10,000 lb. Both types said to fea-



ture ease and smoothness in lifting and lowering load. Designed to handle foundry materials on skid platforms and pallets. *Automatic Transportation Co.*

For Manufacturer's Information Circle No. 414, Page 7-8

DIRECT READING SPECTROMETER . . . can analyze six elements within 57 seconds. Gives direct readings without integration. Suited for practically all cast-metal alloy sys-

Circle No. 547, Page 7-8

■ Details on these products and processes are available to MODERN CASTINGS readers. See page 7-8.

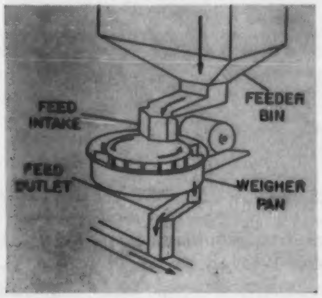
tems. Can be installed and ready for operation within two days. *Intercontinental Electronics Corp.*

For Manufacturer's Information Circle No. 415, Page 7-8

CONVEYOR BELT LACING . . . said to eliminate need for templates, drilling or hole punching. Flexible hinge plate conforms with conveyor trough curvature. Splice can be installed quickly in one piece, giving fit said to be tight and leakproof, yet flexible. *General Splice Corp.*

For Manufacturer's Information Circle No. 416, Page 7-8

CONTINUOUS WEIGHING DEVICE . . . for weighing any dry bulk foundry material. Said to give accurate weight in connection with any type conveying or feeding equip-



ment. Weight indicated in lb-per-min, lb-per-hour, or tons-per-hour. Provides chart record of flow rate for 24 hours. *Stephens-Adamson Mfg. Co.*

For Manufacturer's Information Circle No. 417, Page 7-8

MACHINERY MODELS . . . made from construction kit said to facilitate development of new ideas and creation of machines and mechanisms by designers, engineers, inventors, etc. Developed in Sweden to meet need

for proving workability of designs not thoroughly substantiated before blueprints are finalized and construction started.

Manufacturer claims models made with the kit have sufficient ruggedness, precision, and long wear to make them useful as machines and test equipment for research. Kits made

in two sizes, each with complete instruction manuals and a variety of precision-machined mechanical components. One kit contains 2700 parts, the other 4700.

Kit has been used in Swedish industry to build working models of an overhead traveling crane, articulated rail car, rotary printing press, gang log saw, and others. *FAC Div.*

For Manufacturer's Information Circle No. 418, Page 7-8

ALL-PURPOSE VISE . . . designed to grip any shape of work pieces on at least four points, manufacturer claims, without use of special inserts or attachments. Rotary turret jaw vices available in machine and bench type, jaw openings 2-8 in. *Hudson Automatic Machine & Tool Co.*

For Manufacturer's Information Circle No. 419, Page 7-8

DESIGNER'S LAYOUT KIT . . . said to make it possible for tool engineer to design, pre-price, and order special two or three tool cluster boring

bars from standard components. Kit claimed to allow use of any of 330 boring bars in designing tooling suited to individual semi-production applications. *De Vlieg Machine Co.*

For Manufacturer's Information Circle No. 420, Page 7-8

FRONT END LOADER . . . designed to provide maneuverability, ease of operation, and versatility for intra-plant material handling. Inching valve permits machine to ease into restricted areas by operation of foot brake. Rated payload capacity, 19 cu ft; capacity, 14 cu ft; maximum lifting load, 3000 lb. *Euclid Div., General Motors Corp.*

For Manufacturer's Information Circle No. 421, Page 7-8

SAND DEFORMATION . . . tester for measuring ability of green molding and core sands to maintain their dimensional accuracy under a static load. Measures creep deformation which indicates mold wall rigidity needed for precision castings. Said to provide accurate means for measuring tendency of sand to deform under own weight. *H. W. Dietert Co.*

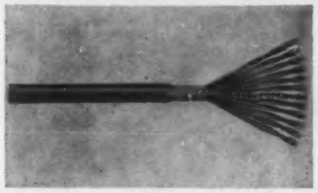
For Manufacturer's Information Circle No. 422, Page 7-8

ELECTRIC BATCH OVEN . . . automatically proportions minimum wattage input in relation to the operat-

■ Details on these products and processes are available to MODERN CASTINGS readers. See page 7-8.

ing temperature and work load for drying and baking operations in laboratories, shops, or pilot plants. Capacities, 16-96 cu ft. Ovens can be operated up to 600 F. *Soiltest, Inc.*
For Manufacturer's Information Circle No. 423, Page 7-8

THERMOCOUPLE EXTENSION CABLE . . . said to greatly reduce cost of installation of thermocouple extension wire when four or more pairs



of wires are needed; saving compared to cost of pulling individual pairs through conduit. Manufacturer claims moisture resistant cable may be hung without conduit, buried, or installed in open trough. *Claud S. Gordon Co.*
For Manufacturer's Information Circle No. 424, Page 7-8

BARREL FINISHING . . . machine said to add new versatility to barrel-finishing and deburring operations. Can be used as single cavity barrel, or compartment barrel with six or more divisions each capable of holding different work and using different media. Sizes to 120 in. *Speed-D-Burr Corp.*
For Manufacturer's Information Circle No. 425, Page 7-8

SELF-CLEANING PULLEYS . . . for conveyors said to insure longer belt life because cone design eliminates material build-up between belt and

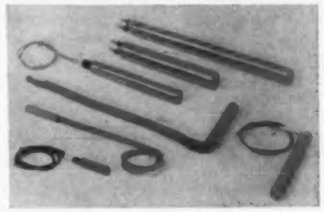
pulley, preventing belt misalignment. Traction provided by oval bar on outside of each wing. Pulleys available in 3000 sizes. *Van Gorp Mfg. Co.*
For Manufacturer's Information Circle No. 426, Page 7-8

PHOTO TRANSPARENCIES . . . made on-the-spot with Polaroid camera. For use in cases that call for

group viewing of slide-projected pictures. Slides available two minutes after picture taken. Process said to be simple, requiring no skilled help. Useful in making copies of pictures or reports and presenting illustrated lectures. *Polaroid Corp.*

For Manufacturer's Information Circle No. 427, Page 7-8

STAINLESS STEEL HEATING UNITS . . . designed for use where concentrated heat is desired and space is limited. Insulating material used to support heating coil said to be best obtainable. Equipped with



nickel alloy fiberglass covered lead wires and terminals. All diameters and lengths. Voltages 115 and 230, with special voltages and wattages available. *C & S Products Co.*

For Manufacturer's Information Circle No. 428, Page 7-8

SHELL MOLDING . . . magnesium silicate refractory said to assure smooth casting surface of steel castings cast by resin-bonded shell molding. Manufacturer claims material inhibits imperfections from gas blow by rapidly chilling surface skin of the metal plus developing sufficient strength to resist outside gas pressure as well as inside ferrostatic pressure. *Harbison-Walker Refractories Co.*

For Manufacturer's Information Circle No. 429, Page 7-8

WATER-GRAPHITE LUBRICANT . . . said to produce high quality, uniform lubricant when water is added for extrusion dies and permanent molds. Jelly-like substance may be applied by brushing or dipping. Differs from other graphite lubricants in that there is no "digging" for graphite which settled in bottoms of jars or drums. *Joseph Dixon Crucible Co.*

For Manufacturer's Information Circle No. 430, Page 7-8

SAND RECLAMATION . . . machine uses gravity feed to eliminate need for variable-speed feeding devices. Discharge setting controls quality and quantity of sand. Compact unit will scrub from 1000 lb/hr up to any requirement. *Beardsley & Piper Div., Pettibone Mulliken Corp.*

For Manufacturer's Information Circle No. 431, Page 7-8

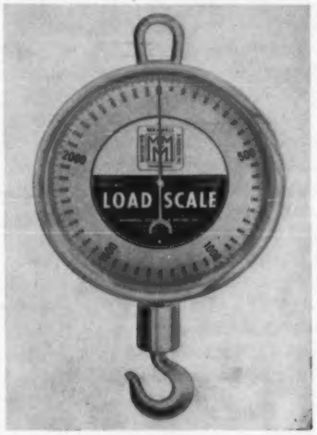
CASTINGS REPAIR . . . taper plug for pinning or lacing cracked castings such as engine blocks, cylinders, etc.

■ **Details on these products and processes are available to MODERN CASTINGS readers. See page 7-8.**

Guaranteed by manufacturer to withstand extremes in temperature and pressures of expansion and contraction. Slotted hex-head permits tightening with either wrench or screw driver, allowing easier access to hard-to-reach places. *United States Casting Repair Corp.*

For Manufacturer's Information Circle No. 432, Page 7-8

LOAD SCALE . . . reduces handling costs by performing weighing and handling in one operation. Said to promote safety by warning against overloading of hoisting equipment. Accurate to 0.2 per cent of full scale reading; manufacturer claims scale is unaffected by the normal temperature ranges of heat and cold. *Manning, Maxwell & Moore, Inc.*



For Manufacturer's Information Circle No. 433, Page 7-8

PORTABLE AIR COMPRESSOR . . . with adjustable pressure from 25 to 100 psi for operations such as tire inflation, paint spraying, cleaning, air driven tools, etc. Single cylinder, 1/3 hp motor, 50 lb. *Emglo Products Corp.*

For Manufacturer's Information Circle No. 434, Page 7-8

the editor's field report

by Jack Schaum

■ As a demonstration of his firm belief in foundrymen's abilities, Henry Ford once said, "Anything that can be drawn up, can be cast." To prove it he cast the first V-8 engine block in 1932. If every metalcasting man will adopt this attitude as his creed, our foundry industry should never want for new fields to conquer. The men who design and the men who buy are showing a new confidence in the ability of castings to meet their challenging needs. Henry Ford's assurance in the versatility of the casting process is reflected in the fact that metalcastings are used in over 90 per cent of all durable goods manufactured in the United States!

■ Plastics continue to push the thermal barrier higher and higher. One enterprising manufacturer has developed a castable plastic which can be used at 425F. One of the most promising applications is for combination core box-dryers. In many instances it has proved helpful to be able to leave the core in one-half of the box and send it through the core oven, with the box acting as a contoured dryer. This is especially helpful and time saving for intricate cores that are difficult to remove from the core box in a green state. The relative ease of making duplicate sets of core boxes with the castable plastic should lead to a growing use for this technique.

■ Safety has no quitting time in The Saginaw Malleable Iron Plant of the Central Foundry Div., GMC. No worker is ever out of sight of safety slogans glaring at him in bold, black letters against a bright yellow background. Strategically placed on plant walls and equipment, are these important messages—Stop, Look, and Live—The Best Safety Device Is a Careful Worker—Safety Is a Habit—Am I as Careful as I can Be—Safety Ever, Accidents Never. Colorful posters prominently displayed, all add up to a working environment that is far safer than the busy streets employees travel to and from the job. Incidentally, the National Safety Council has a poster service, to which you can subscribe and receive a supply of new and different posters each month appropriate to your foundry operations. Drop us a line and we'll be glad to give you all the details.

■ You have all had irksome problems that tried your patience until one day you happened to see how another foundryman solved your problem, by some simple, ingenious innovation. Such a revelation was experienced in a recent visit to the Carondelet Foundry in St. Louis. Like most green sand foundries they wanted to keep dirt from falling into the mold cavity through sprue and riser openings in the mold. So how do they do it? As soon as the finished mold is set aside, a standard conical-shaped Dixie cup is dropped into each of the openings on the top of the mold. Because of their tapered V-shape the cups slip snugly into the cavity, sealing it off temporarily so undesirable dirt cannot fall into the mold cavity. When the mold is poured, the molten metal instantly burns up the paper cup in the sprue and the metal rising in the feed heads destroys the remaining cups. No muss, no fuss, no dirty castings. And speaking of risers, have you ever tried using rice hulls—a waste product—for insulating the tops of steel risers? It's doing a good job for the General Electric steel foundry in Schenectady.

product reports

New missile alloys

. . . used in American missiles signify a major breakthrough for lightweight magnesium-thorium alloys. One such missile, the Air Force "Bomarc", built by Pilotless Aircraft Div., Boeing Airplane Co., makes extensive use of the alloys.

Castings, sheet, and extrusions made of these alloys are the least expensive of airframe materials strong enough to withstand temperatures generated at speeds over 1500 m.p.h.

The Bomarc missile (airspeed, 2000 m.p.h.) incorporates magnesium-thorium sand castings into its airframe because of their light weight and ability to withstand aerodynamic heating. A door frame and equipment-mounting structure cast from the alloy, HK31, saved six lb over the aluminum casting it replaced.

Bomarc is an area-defense weapon designed to stop attacking supersonic bombers. Its range is reportedly over 300 miles.

The alloys were developed by Dow Chemical Co., Midland, Mich.

Circle No. 441, Page 7-8

Barrel finishing machine

. . . makes possible for the first time barrel finishing of inside diameters of castings.

The "Vibraslide" barrel finishing machine shown here being loaded,

is in operation at Metal Finish, Inc., Newark, N. J., a division of Minnesota Mining & Mfg. Co. Success of the process depends on slow barrel rotation combined with vibration of castings and media at 2300 cycles per minute.

Truss rings, for which barrel finishing procedures previously required 40 hours in a standard barrel, are being

processed in the new machine in two hours. Jet blades, formerly barrel finished in 40 hours, are now finished in 16 hours using the vibrating system. Up to three times the number of parts normally run in a standard barrel can be finished at the same time in the new machine.

According to a company official, the speed of the new barrel finishing system is a result of opposing forces within the barrel once the vibratory system is in motion. A double motion is set up, building up resistance within the sliding mass when movement of the vibratory cycle is in opposition to the rotation of the barrel.

Parts such as this magnet armature,

which formerly had to be finished by hand because of small radii, can now be finished with the vibratory system in quantities of 2000 per load in 1½ hours. The two motors and vibrating mechanism composing "power pack" of the barrel finishing machine can be removed for maintenance without dismantling the barrel.

Circle No. 442, Page 7-8

Protective atmosphere

. . . newly developed for use with annealing furnaces has improved the quality of castings and reduced annealing time for the Dayton Malleable Iron Co., Ironton, Ohio.

The Dayton company has recently installed General Electric's 10,000 CFH Neutralene gas producer for production of Neutralene gas as an atmosphere; and reports that decarburization on castings has been practically eliminated. Customers find this of importance in that machining of the castings is done faster and easier, resulting in greatly improved tool life.

In addition, the new atmosphere has reduced the annealing process from 33-hour to 29-hour cycles, and expects to go lower. Rejects caused by torn castings resulting from sheared off gates are now negligible.

The new gas forms an inert atmosphere which purges oxygen from inside the furnace. Prior to installation of the new gas producing unit, the atmosphere in the furnaces was generated by the castings themselves and would vary widely in analysis throughout the heating cycle. Carbon dioxide ranged from 3 to 10 per cent, carbon monoxide from 10 to 30 per

cent, with varying amounts of water vapor and hydrogen.

A typical protective atmosphere formed by the new gas is 1.5-2 per cent carbon monoxide, 1.5 per cent carbon dioxide, and the remainder, nitrogen.

By installing this gas producer equipment the Dayton foundry is now able to reclaim carbon dioxide gas ordinarily discarded from the unit. Purchases of bottled gas totaling several hundred dollars monthly have thereby been eliminated.

Circle No. 443, Page 7-8

Lighting Conference at University of Michigan

■ The University of Michigan, in collaboration with the Illuminating Engineering Society, is offering a three-day course, conference, and clinic on lighting, entitled, "Light and Vision," Mar. 19-21.

Goal of the conference is to outline principles that govern seeing in various lighting environments, and measures that most effectively employ these principles in creation or adjustment of lighting environments to optimum conditions for seeing.

The meeting will be designed to serve industrial hygienists in industry and official agencies, as well as public health personnel, school administrators, architects, engineers, and others.

Sales Clinic Emphasis on Castings Sales Techniques

■ Developing better sales programs to increase castings sales for foundries is the goal of a new sales training clinic, "Techniques of Selling More Castings . . . Profitably!", sponsored by Metallurical Associates, Inc., Boston, Mass.

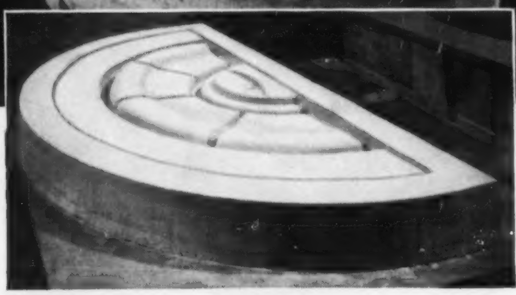
The first of the clinics was held in Philadelphia in February; six other eastern cities will host the clinic durin 1958.

Instructions will cover the use of proven effective sales techniques in the selling of castings. Experienced, successful salesmen will instruct the clinic session, which will be limited in size to insure personalized instruction and active participation. Harold Brown, vice-president, Metallurgical Associates, Inc. is directing the clinic.

Clinics will be held at Cleveland, March 25; Springfield, Mass. in April; Newark, N. J., in May; Syracuse, N. Y., in June; Boston, in September; and Pittsburgh, Pa. in November.

■ To obtain complete information about housing, schedule of events, etc., circle No. B, Page 7-8.

Circle No. 552, Page 7-8



pouring off the heat

In the December, 1956 Modern Castings, *Herbert J. Weber deplored the too-frequent confusion of siderosis for silicosis in his "SHAPe" column. The column was recently referred to a firm of consulting actuaries by Kenyon D. Love, Colonial Foundry, Louisville, Ohio. This precipitated a claim by the actuary that siderosis is not misdiagnosed, and a refutaton by Weber.—Editor*

it ain't so

■ As for siderosis being misinterpreted in a silicosis claim, this is not likely under our Ohio system. The Slicosis Board of Referees makes a complete physical examination, in addition to reading the x-rays. Since siderosis is a nondisabling ailment, the physical examination readily provides a means of differentiation.

Some time ago we had occasion to read some excerpts from papers presented at a meeting at the Saranac Lake Laboratory. From the general content of the information, it appeared that the doctors specializing in the field of silicosis and other industrial lung pathologies, had reached the conclusion that it would be necessary to re-evaluate many of the former standards. We are quite certain that some of these doctors would take exception to Mr. Weber's reference to giving considerable importance to quantitative history of exposure.

R. K. Chubb
Gates, McDonald & Co.
Columbus, Ohio

it is

■ The fact that siderosis is frequently confused with silicosis prompted us to undertake a five-year study costing well in excess of $20,000. The results of this work were published in the April, 1950 issue of *Industrial Medicine and Surgery*. The article is entitled: "Siderosis, a Benign Pneumoconiosis Due to the Inhalation of Iron Dust." The authors were L. E. Hamlin, M.D., Herbert J. Weber, Arthur J. Vorwald, M.D., and associates.

So widespread was the misdiagnosis of siderosis that we distributed 18,000 reprints of this article to various physicians and industrial commissions throughout the country.

To Mr. Chubb's statement on re-evaluating standards, I reply that physicians are not competent to re-evaluate any exposure standards or

to practice industrial-hygiene engineering any more than industrial hygiene engineers are competent in the field of medicine. If any standards are to be re-evaluated, it will require a joint effort.

And to the statement that "since siderosis is a nondisabling ailment, the physical examination readily provides a means of differentaton", I reply that this has been refuted by autopsy showing misdiagnosis and the fact that many silicotics have lived out their life's span because it is possble and common to have silicosis without disability. Hence the need for knowing what the work exposure was.

HERBERT J. WEBER, *Director*
AFS Safety, Hygiene and Air Polution Control Program

reprints available

■ Would it be possible to furnish me with 25 reprints of the article *"Grinding Wheels Are Save—Use—Don't Abuse"* on page 50 of the November MODERN CASTINGS?

This is a very well written article and I should like to give a copy to each of the grinders in our plants.

CHARLES F. SEELBACH, JR.
Forest City Foundries Co.
Cleveland

Reprints of this article will be made available to any other reader who wants them for distribution in his plant.—Editor.

missionary work

■ I read with interest the entire January, 1958 issue of MODERN CASTINGS, but the article of particular importance to me was the article on page 26, *"Chance Vought Uses More Steel Castings,"* by S. K. Hodgson.

Here at Aerojet we have many opportunities for conversion to steel castings and I wculd like to circulate copies of this article to the design engineers concerned.

Please send 10 copies of this article so that they may be used to aid the conversion of weldments to steel castings.

R. CLARKE STANLEY
Aerojet-General Corp.
Liquid Rocket Plant
Sacramento, Calif.

sound asleep

■ I have just slept through another interesting talk on foundry practice in spite of all human efforts to stay awake. And I'm mad because I really wanted to hear the speech. Unfor-

Continued on page 22

tunately I was mesmerized into the state of unconsciousness by several inexcusable tricks.

First the speaker turned off all the lights leaving his audience in total darkness—the perfect environment for napping—so he could show some slides. Why can't people realize the advantages of having a few dim lights left on in the room. The speaker can see his audience and vice versa; if you want to take notes you can; and if some one comes into the room late they can find a seat.

Then comes the really low blow. The whole talk is built around a series of slides that can only be seen by the man giving the lecture. Lettering on the graphs, charts, and tables are so small and so light that nothing meets the eye but a fuzzy blurr. Make the letters at least twice as large and four times as heavy as normal. Don't use a typewriter as a substitute for india ink and hand lettering. Better to have less information on the slide and have it readable.

Of course good legible slides can be sabotaged by using a projector with a weak bulb that won't light up a screen 20 feet away. Let's at least have a 500 watt bulb in the machine.

Take these sedatives out of your technical meetings and keep your audience alert instead of asleep

DISGRUNTLED FOUNDRYMAN

wide awake

■ I've been wanting to join AFS for the past six years, but between trying to straighten out this or that molding job and trying to work out this or that core blowing job; or trying to fix this or that 100-year-old pattern with enough gumbo to help old "Pop" get it out of the sand; I've generally felt just able enough to get my dirty size "8's" up on my wife's clean hassock and read about what's going on with the rest of the crazy fools in the world—(including those in Washington).

So—since this is one of my rare letter-writing moods, hurry up and send me all the dope I need to make me part of AFS.

No sense in being left out of the running when there is so much to learn these days.

TOM BROWNELL
PHENIX CITY, ALA.

Looking . . .

for new ideas?

Circle the numbers on Reader Service cards page 7-8 for additional information on products, services, and advertisers' literature. Circle the letters for tear sheets on feature material.

Industry Must Act to Save Employees from Radiation

■ No quantity of radiation, no matter how small, is known to be beneficial to the human body; overexposure to all kinds of radiation causes injury by damaging or killing the tiny living cells of the body. "Radiation" is intended to refer to alpha and beta particles, electrons, protons, neutrons, gamma and x-rays.

Effects of Radiation

Overexposure may occur either from working with radiation under improper conditions or from improper handling of the material itself. In the former, the exposure is usually over the entire body, due to faulty shielding or failure to obey distance requirements.

Habitual or long continued overexposure to the hands may result in dry, reddened skin which cracks easily and is very sensitive to heat and cold. Finger nails become brittle, and small cracks or sores form on the hands. Cancer may develop. Exposure to radiation should be stopped long before this stage.

Protection

Little can be done in the way of curative medical treatment for employees who have received sublethal and lethal doses; much can be done toward preventing them and others from accumulating still more in their systems. The problem is to know when those with small exposures have arrived at the stage requiring a change of job.

A health-physics unit in the plant should be prepared to check and recheck the exposures to the worker and their effects on the worker himself. There may be apprehension on the part of some workers; such situations demand careful handling and presentation. Continual education is imperative.

Constant review of employee exposure records, as well as their clinical records, is necessary to aid in maintaining employee maximum health. Also necessary are well-trained personnel with laboratory facilities for special tests of blood, urine, sputum, and stool specimens. However expensive, laborious, and exacting, these procedures are extremely important for protection and well-being of persons exposed to radiation.

■ *This article is based on the "Health Aspects of Radiation" chapter of the American Foundrymen's Society Radiation Protection Manual. The chapter was written by Dr. M. H. Kronenberg, AFS Radiation Protection Committee.*

Roundup of DUCTILE IRON Technology

DAVID MATTER / *Manager*
Iron Foundry Service,
Ohio Ferro Alloys Corp.
Canton, Ohio

Prospective ductile iron producers should have this background knowledge before attempting to make this alloy

One of the most significant advances in the castings industry during the past decade has been the discovery of an entirely new material—ductile iron. In the period since its 1947 introduction, ductile iron has achieved a growth rate varying from 60 to 100 per cent increase per year. Now being produced in about 140 U. S. foundries, its growth pattern indicates that before too many more years ductile iron may become second only to gray iron in the tonnage poured.

Within this article the terms ductile iron, nodular iron and spheroidal graphite cast iron are considered the same and are used interchangeably. The importance that nodular iron has achieved in the few years since its introduction is evident in both the widespread scope of its applications and the voluminous references which began soon to appear in the literature concerning this material. Few, if any, metallurgical or foundry developments have ever been the subject of as many technical studies and papers in so short a period of time.

No consideration or contemplation of producing ductile iron should be made without a firm knowledge of the complications involved. This article will discuss complexities of melting, gating and risering and their deviations from the practice common for either gray iron or malleable iron.

Nodular iron is a material whose properties are intermediate between those of gray iron and cast steel. Often referred to as an as-cast malleable iron, its properties are not in reality so easily defined. Nodular iron does not represent a single set of properties but rather offers an extremely wide range of those properties useful to the design engineer—high strength, ductility, and wear resistance, without sacrificing the process advantages of cast iron—low melting point, good fluidity and excellent castability.

Many patents have been granted pertaining to methods of producing ductile or nodular iron.

The International Nickel Co. holds patents covering the production of spheroidal graphite in cast iron by means of magnesium additions. The British Cast Iron Research Association has been granted patents covering the use of cerium as the nodularizing agent.

In addition many process patents exist covering melting techniques, methods of alloying, and other procedures involved in producing ductile iron. You should investigate these patents and determine how they pertain to you before initiating production of ductile iron.

■ **Effect and control of graphite form.** Differences between structure and properties of steel castings and various forms of cast iron are caused by the greatly increased carbon content of cast iron. The extra carbon, often as much as ten times the content of low carbon steels, precipitates in a manner that interrupts the continuity of the steel like matrix.

In gray cast irons the carbon is in the form of flakes interspersed throughout the steel matrix. These flake graphite particles essentially act as voids in the material, breaking up the structure and interrupting its continuity. Since graphite has low strength and nil ductility, the graphite in cast iron lowers strength and reduces its ability to elongate. In gray iron, the elongated, sharp-ended graphite provides internal notches that lead to stress concentration points yielding low impact resistance and practically zero elongation.

Improvement of cast-iron's mechanical properties centers about the control of graphite formations. Principally through control of flake-size and distribution, gray cast irons can be produced with tensile strengths ranging from 20,000 psi to 50,000 psi and higher, but with no measurable ductility. Graphite does impart certain desirable properties—wear resistance, machinability, damping capacity, and corrosion resistance.

The addition of a small amount of magnesium creates a startling change in the graphite structure. The metallurgical forces that cause graphite to appear in flake form are altered by magnesium so that the graphite precipitates out with a spherical shape. This change reduces the weakening and embrittling effects of graphite. Spheroidal graphite presents the minimum ratio of surface area to graphite volume.

Thus it creates a minimum number of discontinuities in the metal matrix, resulting in a stronger, tougher material. Once the change in graphite form occurs, the properties can be even further extended through control of the matrix constituents.

■ **Matrix structure.** A variety of matrix constituents can be produced in the as-cast condition through alloy control. Nodular iron with as-cast structure, essentially pearlitic, may have physical properties in the order of 100,000 psi tensile strength, with about 5.0 per cent elongation, and 250 Bhn. This structure finds application in parts requiring wear resistance, fair strength, and impact resistance in the order of three to five times that of gray iron.

Through alloy control, nodular iron can be produced with elongations in excess of 15 per cent as-cast, tensile strengths in the order of 75 to 80,000 psi, and hardness below 200 Bhn. These figures are for 1-in. sections in the standard "Y" block test sample. The softer, alloy-free iron has gained considerable popularity, since it represents a material with several distinct advantages:

- It is now being cast free of primary carbides in sections down to 1/8-in.
- Gating and risering is simplified, foundry yield increased.
- As-cast machinability is improved and heat treating re-

quirements are minimized.

- Appreciable shock resistance can be produced, as-cast.
- It is cheaper.

Ferritic Nodular Iron

Ferritic nodular iron can be produced either as-cast, by annealing, or by a sub-critical temper of any as-cast material free of primary carbides. However, maximum shock resistance requires a full anneal. A full anneal for nodular iron may represent furnace times less than five hours as compared with the considerably longer periods required in the production of malleable iron.

Studies at the Naval Research Laboratory show this material to be as tough as normal grades of mild carbon steel and through rigid chemical control to exhibit superior properties in the field of low-temperature brittle failure. These properties, coupled with good corrosion resistance, led the Navy to approve ductile iron for shipboard use.

Heat Treatment

To produce nodular iron castings with higher strengths and hardnesses than obtained as-cast, the material can be heat treated in a manner similar to steel. Normalized nodular irons, produced by air cooling from above the critical temperature, are pearlitic in structure. This grade offers an excellent combination of strength, toughness, and wear resistance—120,000 psi tensile strength, 80,000 psi yield strength, and five per cent elongation.

The normalized structure is also amenable to both flame and induction hardening. Local hardnesses in the range of 55 to 58 Rockwell C are readily obtained through either of these techniques. Higher strengths can be obtained by employing quench and temper techniques.

The quenching medium is normally room temperature oil. The hardenability of nodular iron is generally too high for water quenching, and cracking may result. Proper selection of tempering temperature permits development of martensite or any of its temper products.

These quenched and tempered nodular irons develop hardness over 460 Brinell, and tensile strength in excess of 200,000 psi. Quenching and tempering permits obtaining a wide range of properties. The relationship of strength (psi) to hardness (Bhn) is approximately 450 times. This factor is useful in determining the probable strength of a part when only hardness can be measured.

Special isothermal transformation products can be produced through quenching into hot salt baths. These techniques of marquenching and austempering produce even more attractive combinations of physical properties.

Chemical Control for Ductile Iron

A foundry can either produce a variety of properties in ductile iron by alloy control; by heat treatment; or a combination of both.

Ductile iron is generally considered as an additional product of the iron foundry. The greatest number of producers by far are from the gray iron field with smaller numbers being producers of malleable or steel castings. However, it is a new material which should be handled in a distinctive manner in all phases of production.

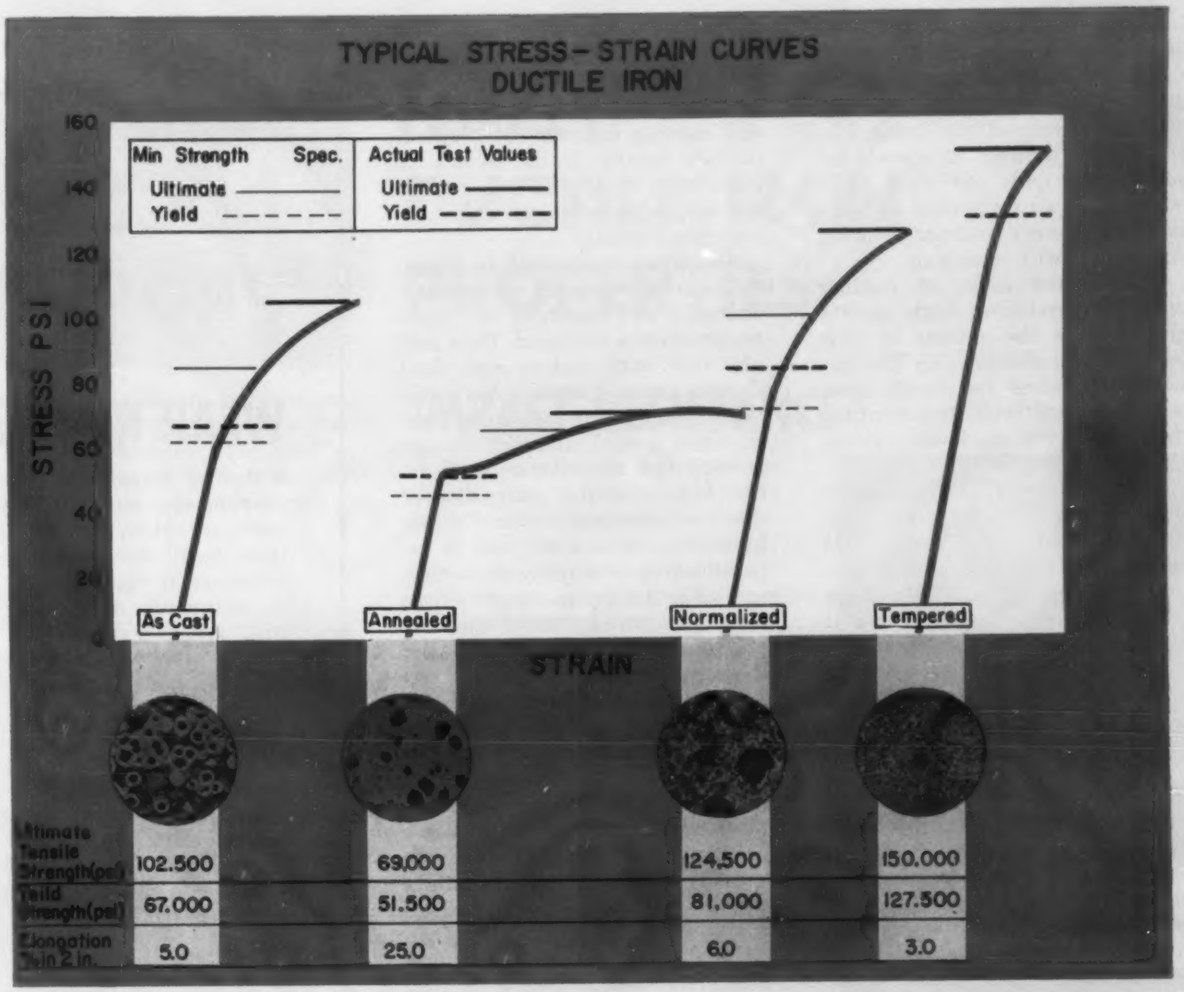
Both carbon and silicon are higher in ductile iron than in either gray or malleable irons. Maximum economy in production dictates that a high-carbon, low-silicon, low-sulphur base iron be tapped from the cupola for subsequent treatment by magnesium bearing alloys and ferro silicon. The desired base iron chemistry is quite different from that desired for malleable iron or an engineering gray iron.

Most melting practices seen to date produce a base iron of approximately 3.80 per cent carbon, 1.00-1.25 per cent silicon, and low sulphur. This analysis has only very limited application in the field of gray iron castings.

Melting Units

Any foundry contemplating the production of nodular iron must realize that no one base iron as yet has been found which is suitable for the production of both gray and nodular cast irons. Various melting units have been successfully employed.

These units include, in the metallurgical and economic order of preference, basic cupola, air and electric furnaces, and acid cupola.



Strength and hardness values greater than obtained as-cast can be developed by heat treating ductile castings. Annealing, normalizing, and tempering treatments similar to those used for steel castings should be used.

Reference to cupolas as being either acid or basic in this discussion should be construed as referring to the chemistry of the slag rather than the nature of the lining material. It is possible to operate an acid-lined cupola for short periods of time with a neutral to basic slag; also many unlined cupolas are running with basic slag.

The desired order of melting units for producing high quality gray iron is the reverse of that preferred for ductile iron The basic cupola, ideal for ductile iron, is extremely difficult to control for the production of lower carbon content gray iron.

Many operators have indicated that it is easier to produce high-quality ductile irons from acid cupola base iron than it is to produce high-quality gray iron from a basic cupola. Electric furnace and air furnace melting yield excellent chemical control but are generally limited to the production of special types of castings.

Sulphur Control

Economic considerations dictate that every effort be made to begin with a low sulphur base metal. Since all of the nodularizing elements are also potent desulphurizers, the initial action of the alloy is to desulphurize the metal before any residual amounts can be retained in the iron. The use of expensive alloys for desulphurizing high sulphur base irons is costly. Some operators melt an intermediate sulphur level and desulphurize in the forehearth with soda ash or calcium carbide to reduce the quantity of magnesium required to produce nodular iron.

For limited quantities of nodular iron both of these methods have achieved certain benefits for the foundryman, but as yet their success has been limited. Operating difficulties usually occur when either of these practices is attempted for any appreciable length of time; though at least one producer desulphurizes continuously in the spout, producing sulphurs below 0.02 per cent.

Gating and Risering

It is impossible to consider gating and risering of nodular iron as similar to any of the other metals. The wide variety of structures which can be produced may each require separate risering systems to obtain maximum yield. Within the entire family of cast irons gating and risering requirements depend on two factors: 1) the degree of super-heat—hence, fluidity; and 2) the volumetric changes which occur upon freezing.

As carbon equivalent increases, the minimum pouring temperature decreases and fluidity at any given temperature is increased. Thus nodular iron with carbon equivalent slightly above gray iron has much better fluidity than either cast steel or white iron. Volumetric change from liquid to solid depends on two factors: 1) the contraction of the iron constituent from superheated liquid to solid; and 2) expansion due to graphite formation.

Within the entire range of cast irons the contraction of the iron constituent is relatively stable. But the expansion due to graphite formation varies greatly depending upon the total carbon content and the percentage of graphitic carbon produced in the as-cast condition. Ductile iron with high carbon in the range of 3.75 per cent and a predominantly ferritic matrix can actually produce sound castings without any risering.

Experience to date has indicated that the feed metal requirements for ductile iron are much closer to those of a high-strength cast iron than to those necessary for producing sound steel castings.

Proper Gating

Metal treatment to produce ductile iron generate large quantities of slag. Good gating practice must insure that none of this slag enters the casting. Trap gating, swirling in risers and positive pressure gating systems are recommended. To insure clean metal in the casting pour hot, fast, and with a tranquil flowing system to prevent oxidation of magnesium as the mold cavity is being filled.

On a jobbing basis it has thus far proved to be difficult to obtain yields above 50 per cent in ductile iron. A few foundries are regularly producing this material with foundry yields close to 70 per cent because they have developed good gating and risering practices.

The position of ductile iron in the castings industry has already been established. Its prime impact in the ferrous casting field is perhaps the fact that the combination of high strength and excellent castability enlarges the scope of the products to which castings may be applied. With the new semi-precision casting techniques, the foundry can compete with forgings and fabrications, capitalizing on the inherent advantages of casting.

Since suitable controls for the economic production of high quality ductile iron involve deviation from the common practices employed for other ferrous metals, it is suggested that thorough investigation of the metallurgical controls necessary to establish economic production be investigated. Unprepared attempts to produce ductile iron castings may result in expensive failure.

■ Photographs used to illustrate this article were supplied by Cooper-Bessemer Corp., International Harvester Co., Walworth Co., and Youngstown Foundry and Machine Co.

PROFILE of DUCTILE IRON PROPERTIES

WEAR RESISTANCE

■ One of ductile iron's most outstanding characteristics is its wear resistance. Many industrial applications have shown that the wear resistance is equivalent to that of the best grades of gray iron. Industrial applications include crankshafts, metal working rolls, punch dies, sheet metal dies, gears, and sheaves.

Compared to steel, the wear resistance of nodular iron, at an equal hardness, is markedly superior. Effect of graphite is to store lubricants for starting-up periods and to prevent galling and scuffing during periods of positive lubrication failure. Pearlitic malleable is often used for wear resistance. But where this is the prime purpose superior mechanical properties can be produced with ductile irons.

In one instance, as-cast ductile iron drive gears for paper mills have operated two years with little evidence of wear on the gear teeth. Gray iron and heat-treated steel gears yielded an average life of but six months in this application.

A heading die, quenched and tempered, for punching out cartridge cases, was still serviceable after producing 900,000 cases. This compares with an average of 45,000 cases per tool steel die. A 20 to 1 superiority.

Hot strip run-out table rolls utilize the wear resistant characteristics of ductile iron castings.

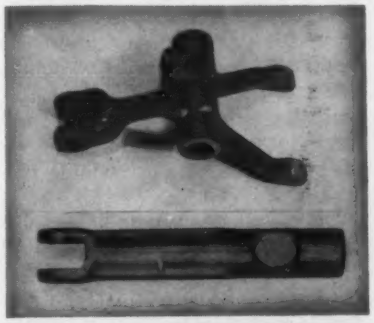
PROFILE of DUCTILE IRON PROPERTIES

STRENGTH

■ As previously mentioned, the strength of ductile irons is dependent upon the structure of the steel-like matrix. The strength of the various grades of nodular iron is in the order of three to five times that of gray iron, making them useful for applications such as these truck wheels.

Compared to ferritic malleable irons, ferritic nodular iron (with equal ductility and impact resistance) will be some 50 per cent stronger. The same comparison is true for pearlitic malleable. Compared to cast steel, nodular iron, at a given hardness, will have an ultimate strength 15% lower but yield strength somewhat higher.

DUCTILITY



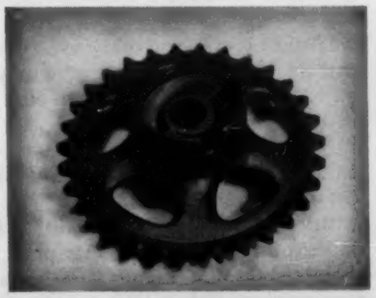
■ Ductility is usually measured by the stretching out and necking down of a specimen tested in tension. Graphitic irons do not neck down in tension tests. Therefore elongations and particularly reduction in area measurements are lower than those obtained on cast steels.

In gray iron ductility is nil. Flake graphite severely interrupts whatever ductility exists in the matrix.

Malleable irons regularly show elongations up to approximately 18 per cent; pearlitic malleable is in the six to eight per cent range.

Nodular iron presents a higher combination of strength and ductility than do malleable irons. Compared to cast steel grades of equal strength, the ductility of nodular irons generally runs one-third to one-half lower.

CASTABILITY



■ The combination of a high degree of fluidity and low-melting temperature allows the casting of intricate parts such as this sprocket which is typical of ductile iron castings used on farm tractors and farm inplements.

Nodular iron has casting qualities comparable to a high-carbon gray iron. Many parts, too intricate for casting in steel, or requiring better properties than gray iron, are now being produced in nodular iron. Section sensitivity of ductile iron is comparatively low. Variation in structure from light to heavy sections is not extreme. Practically identical analyses are being used to pour castings ranging from a few ounces to 50 tons.

IMPACT RESISTANCE

■ Maximum impact resistance for ductile iron is produced by the fully ferritized grade. Approximately 15 ft lb on the notched charpy test is the ultimate obtainable.

This is comparable to a 0.40 per cent carbon steel, normalized and tempered, and equal to that of a ferritic malleable iron.

Ductile iron has found many applications where impact resistance and vibration damping at extremely low temperatures are important. Pictured is a fender stamping die cast in ductile iron to utilize these properties.

CORROSION RESISTANCE

■ The improved corrosion resistance of cast irons over steel in most media increases the pressure applications. Since ductile iron exhibits corrosion resistance comparable to that of gray iron it is being used in pressure vessels where high-operating pressures are involved, and corrosion resistance is needed.

Ductile iron offers excellent resistance to oxidation and growth at elevated temperatures. Furnace doors, grates, and pouring troughs have yielded service life ten times that of gray-iron parts. High silicon enhances the oxidation resistance of nodular iron.

PRESSURE TIGHTNESS

■ Ductile iron is often an ideal material where pressure tightness is the prime requisite. The combination of its high strength and excellent castability impart this property which makes ductile suitable for applications such as this 1800-lb cylinder body used at operating pressures of 1200-1800 psi.

Q. How Can Accidents with Fork Trucks Be Avoided?

A. By Following a Three-Point Program:

1. USE TRUCKS WITH BUILT-IN SAFETY FEATURES

2. MAINTAIN THE EQUIPMENT

3. TRAIN DRIVERS IN SAFE OPERATION

A. E. Dorod / *Consulting Engineer*
Baker Industrial Trucks Div., Otis Elevator Co. Cleveland

The safety of the man at the wheel of a fork lift truck in any metalcasting plant depends on three factors:

- Safety built into the truck by the manufacturer
- Adequate maintenance of these safety features
- Completely safe operation of the truck

Take away any one of these points and, like a three legged stool, a program for the safety of truck operators will collapse.

■ **Safety built into the truck by the manufacturer**. Any piece of equipment must represent the compromise of many factors. Many seemingly desirable features must be modified for practicability.

Most electric truck manufacturers constantly temper their design with a view toward safety. While all of the safety features discussed here are not adhered to by all electric truck builders, yet one or more manufacturers follow them in their entirety. But what are some of these built-in safety features?

■ **Dead man control**. If a man should fall or be knocked off a truck, or even steps off—the power is automatically cut off and the brake applied—This without any voluntary action on the part of the operator.

This feature has probably been adopted by all builders of electric industrial trucks and applies to "sit down" as well as stand-up models.

This is accomplished generally by a spring applied brake. It is kept open during operation by the operator standing on a pedal or platform, or by sitting on the seat.

■ **Cut-out control switch**. Linked to this same platform or seat is a switch which permits the truck to be operated only when operator is in driving position.

■ **First speed control pickup**. This is a control switch arrangement, whereby it is impossible to close circuit for operating current, except in lowest speed. If control lever is placed in a higher speed position, truck cannot accidentally start up when operator steps on operating platform or pedal, except in lowest speed.

In most cases where an accelerator type of speed control is used, the previously mentioned switch is eliminated, because this type control is spring returned to neutral or off position.

■ **Fast disconnect plug**. In event of a "frozen" contactor, it is only necessary to flip the locking lever, and this plug disconnects all battery current.

■ **Dynamic braking**. This prevents plugging the motor, with its attendant dangers of breaking axle shafts, stripping gears, the causing of frozen contactors, spilling loads, etc.

It also is a positive speed control in descending ramps. Many potential accidents have been eliminated by this device.

For those unfamiliar with dynamic braking, it is accomplished by completely disconnecting the battery from the motor circuit and substituting resistance in its place. Thus when the momentum of a truck drives it forward or reverse as the case may be, the motor then acts as a generator and the current is dissipated as heat in resistors. Without dynamic braking, motor is connected to battery, and when controller is reversed, battery current tends to reverse motor with its attendant stresses to cause breaking strains.

■ **Automotive-type controls**. Many of the newest designed lighter weight trucks have adopted controls similar to automotive on the premise that an operator, having to change type of controls after driving to work, was prone to accident during the early morning hours. To circumvent this, automotive steer, sit down control, accelerator type speed control and automotive type brakes were adopted.

■ **End control vs center control**. There is still controversy over end control versus center control from a safety standpoint. Some claim that end control permits faster egress in event a truck goes off a dock, while others claim far greater safety to the operator in the center-control truck.

The earliest trucks had load carrying platforms and were end-controlled. Because it was possible to back into obstructions with danger to the operator, guards were added to protect the operator. These varied from about 15 in. high up to waist high. Some companies, because of their safety program specified guards shoulder high.

This illustrates how sometimes the very safety we try to insure can in itself create a dangerous hazard.

In the case of the shoulder high guards, an operator couldn't possibly get out of a falling truck.

Another feature of the earlier

Don't move the truck in forward or reverse until certain that the aisle is clear and unobstructed.

Face direction of travel, and never travel with view obstructed. Proceed slowly and sound warning signal when approaching hazardous area. Travel with forks 2 in. above floor.

Overhead guards must be used when truck is used for overhead stacking. Guards should be strong enough to deflect the heaviest possible object that might drop onto the vehicle.

trucks were mechanical lift devices. Because these were powered both up and down, it was possible to lift up the front end of the truck if the power wasn't cut on reaching the floor. This led to the addition of slip clutches, mechanical cut-outs and electric limit switches. Because at times those would not function, and with its attendant danger, the mechanical lift was replaced with hydraulic.

■ **Hydraulic lift.** The hydraulic lift system has many things in its favor from a safety standpoint. The control valve is so set that overloads cannot be lifted, to cause overturning of truck and throwing load. Hydraulic controls are spring centered in off position and the metering control permits the lowering of the load as slowly as desired. This has a very high safety factor.

■ **Tilting masts.** Tilting masts are built into these trucks as a further measure of safety in driving. Even with a sudden stop the load will not be thrown, if fully tilted and carried as it should be, close to the floor.

As a further safety factor, the manufacturer specifies a load reduction as the lift increases. This to maintain correct stability of the truck.

■ **Center of gravity.** Great care is exercised in the design of a truck to maintain a correct center of gravity location to eliminate tipping. The stability of a truck must be a definite compromise between keeping truck as light as possible for floor loading and heavy enough to prevent overturn.

■ **Overhead guards.** This protective device should be furnished wherever high stacking is required. These guards should be amply heavy to deflect the heaviest possible object that could drop onto the truck.

■ **Visibility.** This is a very important feature in industrial trucks. Mast should be as wide spread as possible, if vision is between channels, and close together if operator is off to one side. Some masts are built with one pair of channels nested inside the others. This not only aids in visibility but makes a telescoping structure that is most secure.

■ **General safety features.** Safety paint is in use by most truck manufacturers today. A bright safety orange is used and in some cases striped with broad diagonal black lines to call attention to vehicle approach. Electric horns are supplied except in hazardous atmospheres where hand operated signal devices are used. Many trucks are now equipped with stop lights.

To protect the driver, some manufacturers build a protecting cowl in front of the driver. Where this is true, no controls or levers should extend into the operator's area to cause difficulty in leaving the truck.

Where hazardous atmospheres are encountered, spark-enclosed trucks are available. All sparking devices are sealed within housings with 1/2-in. seal to atmosphere and thermal cut-outs are placed on all heat producing surfaces to prevent current supply in event such surfaces should reach a dangerous temperature.

■ **The adequate maintenance of built in safety factors.** Insist on maintaining the safety factors already built into the truck. Set up a preventive maintenance schedule. Follow this schedule when making a safety inspection every week when the truck came in for lubrication.

A check list of all points to be carefully inspected should be provided for the vehicle maintenance mechanic.

This should not absolve the driver from making an immediate report if he finds something amiss. When such a report is made, it should be examined at once to determine whether the continued use of the truck could constitute a hazard. *If so, the truck should be taken out of service then, not an hour later, not even five minutes later.*

As a further maintenance check, every operator should check his truck personally each morning before starting operation. He should check his brakes, the various ing motions. He should also make certain he is starting out with a speeds, steering, hoisting, and tilt- fully charged battery.

These checks take only a few moments but may save a lot of trouble during the day. Safety devices are valueless un-

High Tiering of loads calls for extra precautions. No truck should be used unless equipped with overhead guard and carriage backrest.

Inspect floors of trailers and box cars before entering with a lift truck. Lay steel plates on trailer or car floor. Set brake and block wheels of tractor and trailer before using lift truck.

less kept in perfect condition. Brakes should be kept in proper working order; steering units, together with rods, pins, tires, wheels and bearings should be kept in condition.

Battery should be properly maintained. A run-down battery can cause contactor sticking and attendant accident.

Hydraulic hoses should be checked and chains or cables inspected and replaced as necessary. It is possible for the hydraulic hoses to chafe and wear to a point that the hydraulic pressure will rupture them. Make sure all nuts are in place and tight, with cotters in position where required. Check wiring and replace before chafing permits shorting.

■ Completely safe operation of the truck. The third point of this three point safety program is operation. This includes the selection and training of the operator, actual truck operation and plant housekeeping. Generally, too little thought is given in the selection of an operator. Many companies pick their operators from unskilled labor, notwithstanding the fact that every piece of motivated equipment is a potential engine of destruction. Trucks costing from \$5000 to \$50,000 are entrusted to these unskilled workers where damage to products, equipment and buildings can run up into many thousands of dollars.

It is not enough for the manufacturer to build-in every conceivable safety device. It is not enough to properly maintain every truck. Safety must be practiced by every operator—it is his responsibility to carry safety to its final conclusion. Too often a serious accident has been caused by the operator due to carelessness, recklessness, day dreaming, anger and poor judgment in emergency. These hazards can be eliminated by the proper selection and training of the operator, together with that operator's complete cooperation.

Following are some of the more flagrant violations of safety ethics which can lead to accidents:

■ Truck overloading. Don't overload truck. Stay within its rated capacity and carefully observe floor load limits. Always inspect the floors of boxcars or highway trucks before entering with industrial truck. If floors are questionable, report at once to superiors. Lay steel floor plates to distribute truck load over greater area.

■ Carelessness in loading. See that brakes are set and wheels blocked on highway trucks or trailers before entering with industrial truck.

Bridge plates should be amply wide to make turns into and out of trucks and freight cars. They should be amply heavy for the loads handled and well secured. It should be ascertained that trucks are out and dock boards removed before moving freight cars.

■ Careless handling. The load should be examined before it is picked up. Do not load broken pallets. Defective pallets can spill loads causing injury to personnel and damage to products. Be careful where unstable loads must be handled and slow down operation accordingly. Where the projecting loads must be handled, extreme caution should be exercised. Some operators attempt to push loads either by backing into them or with forks. Much damage can be done to products by this means.

In picking up load, forks should be properly spread to suit the width of the load, and the load carried back against the carriage. Furthermore, a load should never be picked up off center. An off-center load can cause stretching or breaking of the chain and shifting of load while traveling.

When high tiering of loads is required, extra care should be used. No truck should be used for high tiering unless equipped with suitable overhead guard, and carriage backrest.

■ Careless operation. Tilt loads backward when raising, lowering or traveling, and carry load as low as possible for less danger of tipping and better visibility. Never raise or lower load while traveling.

Lower loads slowly and stop them gradually. One of the important features of hydraulic lifting is the fact that the valve can be metered to control lowering to desired speed. When handling bulky loads it is well to travel backwards for better visibility. It is also well to descend ramps with load trailing, to prevent load from sliding off. Always use dynamic brake in descending ramps. If truck is not equipped with dynamic braking, descend with power off and brake applied before truck has picked up momentum beyond its normal high speed.

■ Careless driving. Always face direction of travel, and never travel with view obstructed. Never start truck in either direction without first making sure path is clear.

Always observe plant traffic regulations. Travel only at safe speeds; and always go slowly around corners and approaching intersections. Keep to the right in two lane routes and never travel in wrong direction on one way lanes.

Approach swinging doors squarely and in the center. Slow down when opening doors by remote control, so you are prepared to stop in event path beyond door is not clear. Proceed slowly when approaching points of danger. Always cross tracks diagonally.

Always sound warning signal when approaching blind corners and other hazardous locations.

Avoid making sudden and jerky stops. Momentum of load can cause it to slide. This must be watched very carefully after load is elevated for stacking.

Brake to complete stop before changing direction of travel. When traveling stay within marked lanes, never travel two abreast and do not follow another truck closer than 15 ft. Watch rear end swing when turning corners, and watch overhead clearances. Make certain your load will clear. This is particularly true when working around overhead pipes, sprinkler heads and ducts. A great deal of damage can be created by knocking off a single sprinkler head.

Keep clear of loading dock edges, pits, and stairwells.

Avoid hitting walls, columns, pipes, fire doors, and elevator gates.

■ Careless housekeeping. Keep passageways clear and never set loads down where they can trip people. Do not operate trucks in aisles where scrap and chips are allowed to accumulate. Also keep passages clear of water, ice, snow, oil and grease. Do not permit roadways to deteriorate.

Never travel with forks raised—keep them about 2 in. off the floor when traveling and flat on floor when parked.

Never park trucks where they will block aisles, loading platforms or doorways, and never park on ramps.

■ Disregard of personal safety. Allow only authorized persons to drive trucks. Many accidents have been caused by some one who was not capable attempting to drive a truck. Do not carry passengers and allow no one to ride on forks. Don't use fork truck as an elevator unless using a properly attached safety platform.

When operating truck, keep arms, legs, hands, and fingers away from mast and other moving parts.

Report faulty truck performance immediately. Repairs should be made at once. The longer repairs are put off, the larger they get. In addition, operating hazards increase with faulty performance.

In conclusion, it should be said that while industrial trucks are being built immeasurably safer than any other motivated equipment, *the end result of their safe operation rests in adequate maintenance, good housekeeping, and inteligent safe driving.*

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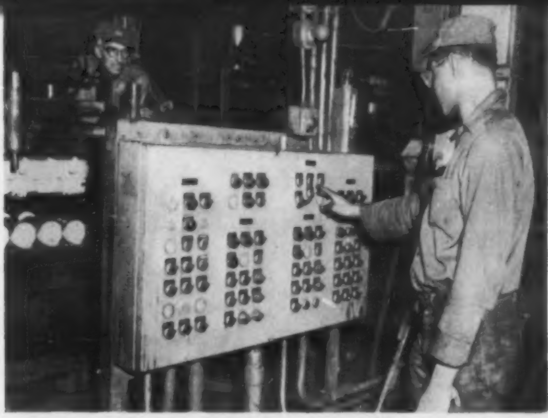


Panel controls automated line where 20 men make what 68 produced before automation.

Pre-assembled cores are transferred by a fixture which lifts the core assembly as an entire unit.

Four-station molding machine fills, jolts, squeezes, and draws the mold.

AUTOMATION IN THE FOUNDRY

PONTIAC FOUNDRY POURS 150 V-8 BLOCKS PER HOUR

Automation is an established fact at Pontiac Motor Div., General Motors Corp., Pontiac, Mich. For two years, an automated line in the Pontiac foundry has been producing 2400 V-8 engine block castings per day.

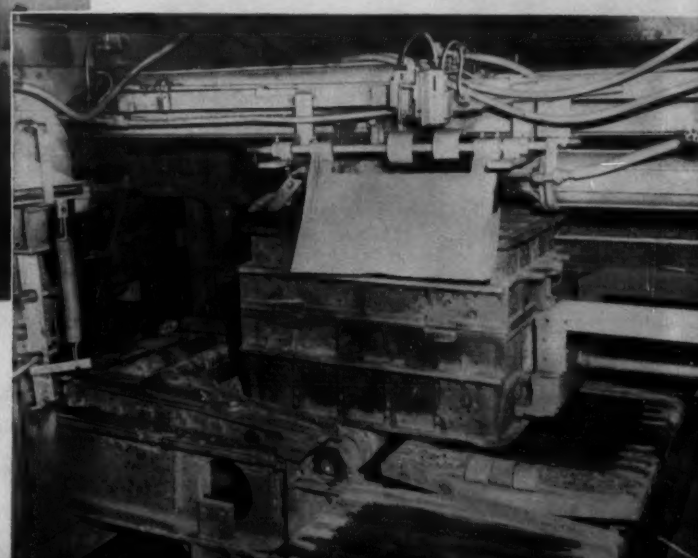
The automatic system makes the molds, closes, and shakes out without any manual handling of the flasks. Functions performed by the 20 men who work on the unit are limited to setting chaplets and cores, pouring, drag spraying, hanging blocks on the cooling conveyor, maintaining a watch on the control panels, and maintaining the mechanical and electrical equipment.

The system performs the complete molding cycle from the time sand enters the molding machine to when the closed mold enters the pouring and cooling line. After cooling, the unit completes the cycle by stripping the cope from the drag, shaking out the sand and castings, and returning the empty flasks to the molding station.

Closing machine lowers cope over cored drag. Line has peak capacity of 200 molds per hour.

Molds moving through pouring area on conveyor are weighed automatically.

After cooling on the conveyor, molds are pushed off into the jolt shakeout area.



PROFITABLE COMPANIONS . . .

SHELL CORES and GREEN SAND MOLDS

Economy and superior quality are advantages claimed for use of hollow shell cores in green sand molds

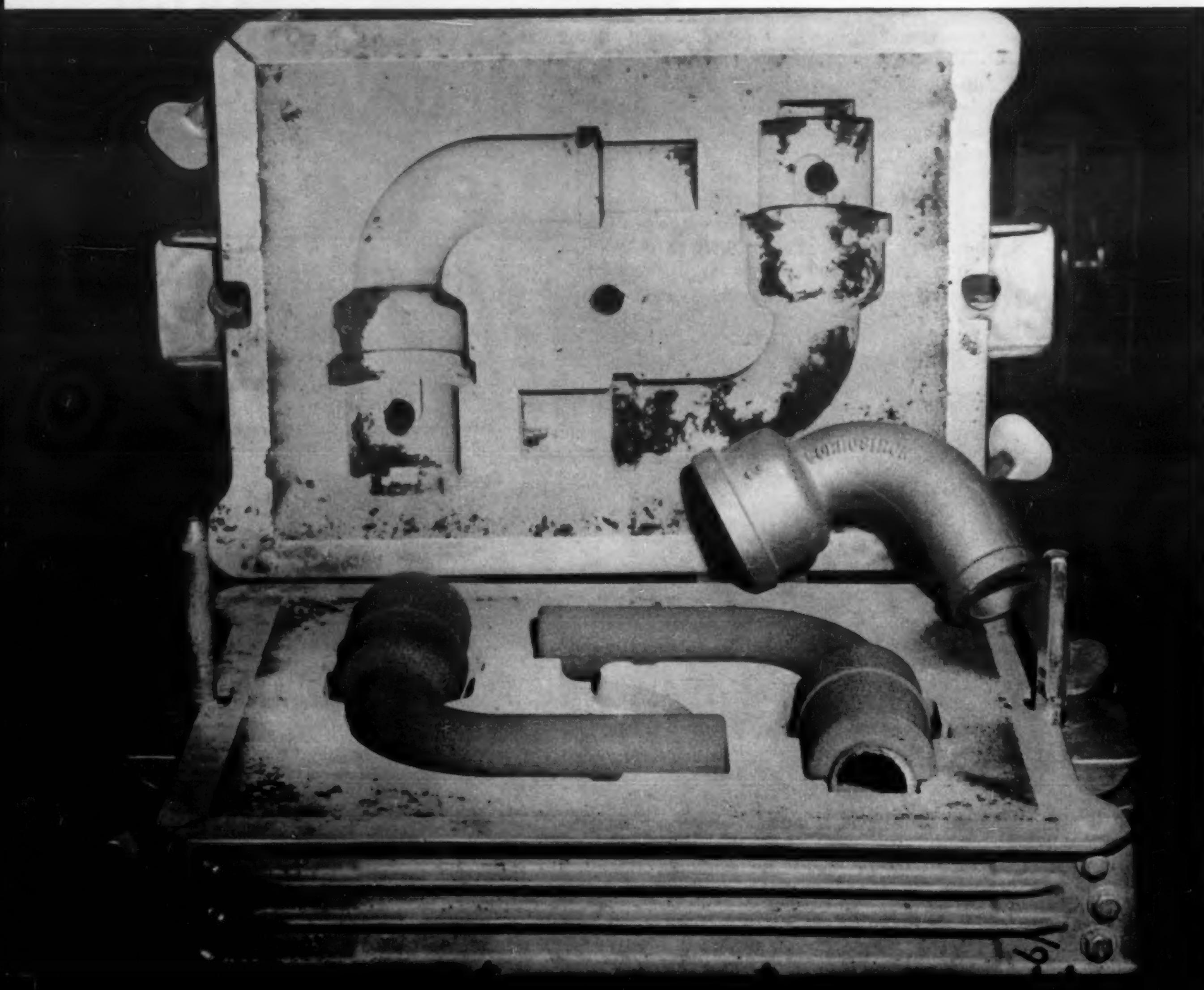
FRANK K. SHALLENBERGER / *President*
Shalco Engineering Corp.
Palo Alto, Calif.

Shell molding was introduced to American foundries slightly less than ten years ago. After an initial flurry of excitement, testing, trial, and error, it has found its rightful place as an important and widely used foundry technique.

Green sand molding is still the preferred method in the vast majority of foundry operations. But shell molding has offered substantial benefits wherever close tolerances, fine surface finish, detail, freedom from surface inclusions and blows, and reduction of scrap and clean-up are of major importance. In many cases it has competed effectively on a cost basis alone.

Today, castings ranging from valves and fittings to crankshafts, tube mill piercing points, cylinder sleeves and heads, motor frames and end bells, bearings, machine tool components, gears, cams, and thousands of other items are being successfully produced in shell molds, with new ones added daily.

70 per cent labor cost reduction was claimed when shell cores replaced conventionally blown and dried cores in this 2 in. iron pipe fitting. Core weight was 1/3 conventional core, and clean-up time reduced 50 per cent.



Shell Cores

Compared to shell molding, the growth in use of shell cores has been even more dramatic. Shell cores have found greater application in green sand and permanent molds than in shell molds. Well over three-fourths of the shell cores produced today are set in green sand molds. This is not surprising when considering the inefficiencies of conventional core making techniques. Wires, driers, ovens, washes, pasting, can all be eliminated by using shell cores.

Shell cores offer all the benefits of shell molds—finish, precision, detail, metal quality and reduction of subsequent machine operations. They provide venting and collapsibility far superior to that of any other core-making technique. And in most applications, shell cores offer substantial savings in materials, labor and equipment.

These savings have been so widely and effectively demonstrated that it can safely be said that whenever core production is adequate to justify metal boxes, shell cores warrant serious and careful consideration.

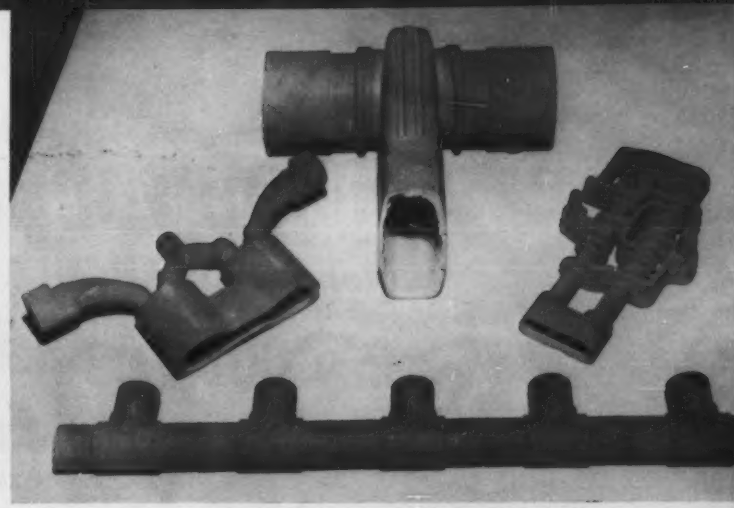
Cores are Hollow

Shell cores are hollow. Wall thickness varies from 1/8-in. to 1/4-in., and the hollow cavity represents pure savings in material. Shell core sand and resin cost about three times as much as oil sand core material. Therefore hollow shell cores can compete on materials costs alone with conventional cores when their weight is one third or less that of solid cores. In many cases shell cores weigh less than one-tenth as much as the solid cores.

There appears to be no limit to the size of shell cores. Pipe fittings up to 12-in. diameter and other

Conventional core for 1 lb aluminum casting weighs 1-1/2 lb; shell 1/4 lb.

Setting this 20-lb core is a one man job; 60-lb conventional core took two.



Typical shell cores for use in green sand include a "treed" pipe tee made at rate of 10,000/day/operator.

castings up to five feet in length, are being successfully cored on a production basis. Shell cores only 1/4-in. in diameter are also yielding attractive savings.

When shell cores are removed from the machine, they are complete and ready for setting. Wires, arbors, driers, ovens, secondary handling, and washes are eliminated. One of the greatest savings is the elimination of pasting. Even the largest cores can usually be blown in one piece.

Because of their light weight, the setting of large cores, formerly requiring several men and overhead handling equipment, can now be performed by one man. Shakeout and cleaning are greatly reduced. Equipment costs are low and little skill is required, since temperature, pressures and the operating cycle itself are controlled by the machine.

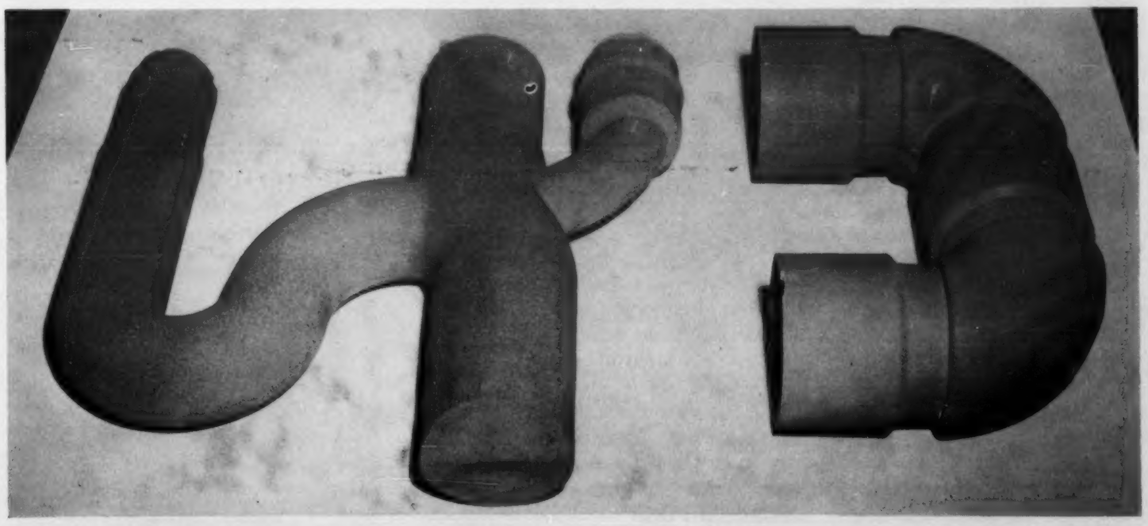
Past concern with contamination of heap sand appears to be unfounded. Most of the resin is burned out during pouring. Remaining resin-bearing lumps are screened out and clean silica sand returned to the heap.

High Production Rates

Shell coremaking can be readily automated. In production operations, a single operator can tend up to three shell core blowers. Productivity is high, especially when the recently-developed technique of "treeing" is used for simultaneous blowing of multiple cores in large multi-cavity boxes. Using this method over ten thousand 1-1/2 in. pipe tees per day may be blown in a single 8-in. x 30-in. box The greatest savings are realized when patterns are rigged to match the core box and a single multi-core tree or grid is blown and set for each mold.

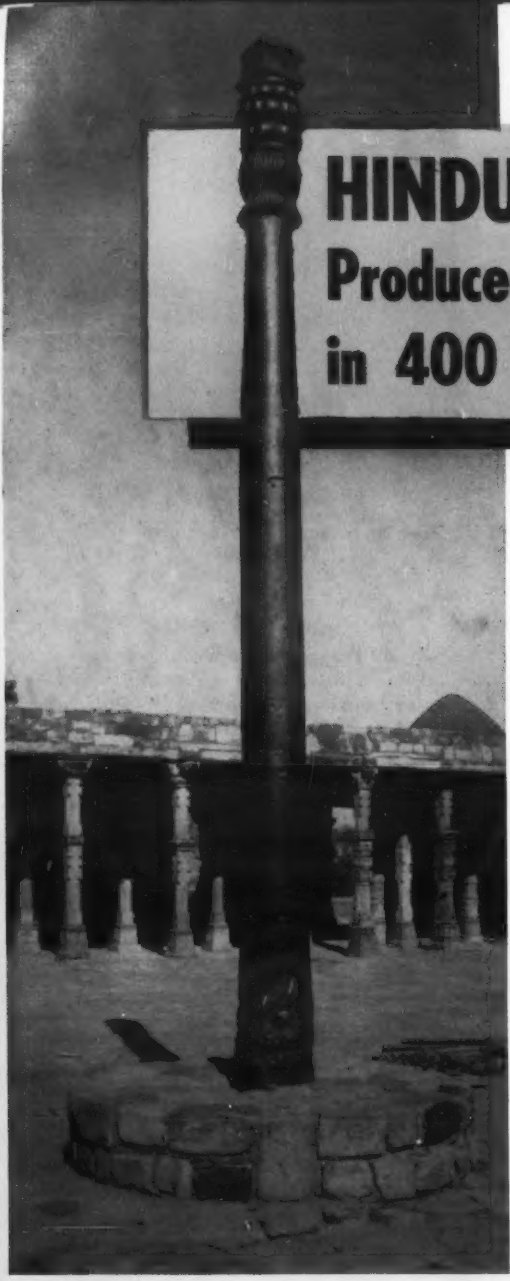
Core blowers capable of handling boxes up to 48-in. x 52-in. have been built, and standard models up to 30-in.x x36-in. are available. These large machines may also be used for blowing double faced shell molds for stack pouring.

Whether the foundry is pouring in shell molds, permanent molds, or green sand molds, the possibilities of shell cores should not be overlooked. Whenever castings with a cored diameter of more than 1-in. are being poured, whenever production is adequate to justify metal core boxes, or wherever troubles with blows, tears, shakeout, finish, or tolerance are faced, shell cores can in all probability offer savings.



Equipment costs for producing these shell cores are said to be 30—60 per cent less than conventional methods.

Bronze bearing is made with 1-lb core; oil sand core weighed 7 lb.



HINDU FOUNDRYMEN
Produced High Purity Iron Castings in 400 A.D.

Composition of Ancient Pillar Parallels Modern Ingot Iron

	Ancient Pillar (per cent)	Modern Ingot Iron (per cent)
Carbon	0.080	0.012
Silicon	0.046	trace
Sulphur	nil	0.025
Phosphorus	0.114	0.005
Manganese	nil	0.017

Man Singh / *Proprietor*
Greysham & Co.
Delhi, India

The ancient Iron Pillar of Qutab, near Delhi, India has stood for centuries as a monument to the metallurgical prowess of the civilization which existed in India before the coming of Christ.

Erected in 400 A.D. by Maharaja Chandra to immortalize his conquest of Bengal, the pillar has long had metallurgists in a quandry as to whether it is a one-piece casting or a series of forged plates welded together to form a column—see American Foundryman, Oct., 1950, *India's Mystery Pillar, Casting or Weldment?* It is now established without doubt that it is a wrought iron single piece casting of pure iron.

The pillar is 23 ft 7 in. in height, 3 ft of which are imbedded under ground. It is tapered from bottom to top, having a circumference of 59 in. at the base, and 38 in. just under the capital which tops the column. The iron is soft enough to be easily marked with a penknife. Pillar weighs over six tons.

The quality of the iron has been a constant source of amazement for metallurgists; just how the ancient Indians were able to cast an iron pillar which has withstood the weathering of 1500 years with no sign of corrosion is still a mystery. The inscription is as sharply defined to-day as the day it was cut.

One of India's invaders, Prince Nadir Shah, determined to uproot the pillar in 1738 out of resentfulness to any monument extolling another monarch. After every effort had failed, the Prince ordered his men to fire a cannon at the pillar; the scar from this unsuccessful attempt at destruction is plainly visible today.

The process employed to give to the iron its amazing properties remains a mystery; its composition, of course, is known. Early in the 1920's Sir Robert Hadfield made a chemical analysis of the pillar: carbon, 0.080%; silicon, 0.046%; sulphur, nil; phosphorous, 0.114%; manganese, nil; total impurities, 0.246%; and specific gravity, 7.81.

India Claims First Iron

Not only did the early peoples of India develop superior quality in cast iron, but, original production of the metal is attributed to that country. In the oldest of the four books of the Veda, books as essential to the Hindu religion of India as is the Bible to Christianity, reference is made to the replacement of the leg of a young woman by an "iron limb." Scholars date the book, called the *Rigveda,* at 1000 B.C.

The *Chark,* a great treatise on medicine, was written before 3000 B.C. In this book appears the statement, "alkaline solutions are to be preserved in iron pots." This is quite startling in view of Bruce L. Simpson's statement in *Development of the Metal Castings Industry* that the Iron Age is generally considered to have commenced about 1200 B.C.

The first invasion of India occurred in 326 B.C. by the army of Alexander the Great. He was presented a 30 lb piece of iron by Porus, King of India, an act of historical importance. In a statement made in 1837 by J. M. Heath, of the Indian Iron and Steel Co., Ltd., he says the act "establishes beyond doubt that the metallurgy of iron was not known to peoples of Greece at that time."

According to Herodotus, the Indian contingent of the army of Xerxes was using iron in the form of military weapons about 500 B.C. At this time Indians were also using iron in medical implements. Herodotus states that nearly 100 such surgical instruments were used "in delicate operations."

Quoting J. M. Heath again, regarding the birthplace of steel production, "We can hardly doubt that the tools with which the Egyptians covered their obelisks and temples with hieroglyphics were made of Indian steel. There is no evidence to show that any of the nations of antiquity besides the Hindus were acquainted with the art of making steel."

From a few tangible fragments such as the iron pillar of Qutab, we are able to catch a glimpse of what was once a great culture; a culture capable of producing centuries ago that which baffles modern man. And what destroyed this ancient civilization of India but the father of all destruction, *war;* following the invasion by Alexander, the continent was invaded from the North by many countries for centuries. Under such circumstances, no advancement in any field is possible.

■ To obtain single additional copies of this article circle C, Reader Service Card, pages 7-8.

Capital which tops the iron pillar 20 feet above ground.

GOOD Practices with BETTER Refractories for BEST Ladle Lining

J. H. Rickey, Jr.
Vice-President, Sales
Ironton Fire Brick Co.
Ironton, Ohio

Castings quality is greatly affected by ladle refractories; improve your practices for increased profits.

Progressive foundrymen are vitally interested in refractories because these heat resistant materials comprise an important part of their production costs. Often the lining materials for the ladles are relegated to secondary importance because they do not seem important enough for any special care or study. True, the volume of refractories used may be small but their effect upon the castings produced and the corresponding profits effected are extremely great. Each foundryman should analyze his ladle practice to see if it is possible to find better refractories to produce time saving, longer lasting service.

To further emphasize the importance of ladle refractories, it might be well to consider that except for possibly some crucible melting and induction furnace charges which are poured direct, all metal comes in contact with a ladle refractory before it is poured into a casting.

A number of factors must be considered when determining the most economical ladle lining to use. The first of these is the initial cost of the refractories. A second item is the cost of installation—becoming more and more critical as labor rates go up. Third, the length of service obtained, whether measured in hours, days, or number of tons poured.

Finally, there is a fourth factor, not often considered and sometimes difficult to evaluate. That is the effect of the refractory lining on the metal quality. Does it react to form more slag which may enter the casting and produce scrap? Does slag adhere to the lining and reduce ladle capacity?

Large Receiving Ladles

Consider now the various types of ladles and the refractories that may be used. Forehearths, mixing ladles, holding ladles, or desulphurizing ladles are quite similar and usually large. They will be discussed first since they receive the metal directly from the cupola. Super duty and dense high duty fire clay brick have been used with success in these ladles.

The table shows comparative data between high duty and super duty fire clay brick.

It is important to lay up these brick with a high quality, air setting mortar to prevent any slag or metal penetration at the joints.

Plastic fire clay has extreme shrinkage and cracks develop in the brick joints. Metal easily penetrates these cracks causing hot spots and rapid failure. Clay mortar has weak green strength and offers no structural stability until its ceramic bond is developed at elevated temperatures. Slags and soda ash quickly attack these clay joints which offer no resistance to their corrosive action.

On the other hand, air setting high temperature cement has exceptionally low shrinkage so no cracks are formed into which the metal can penetrate. Due to its air setting properties, high temperature cement gives a strong bond as soon as it dries. It maintains this strength up to its high fusion point, which is as high or higher than the brick themselves.

Lining temperatures in these large holding ladles are high, as the metal is held in the ladle for long periods of time. Thus, a high P. C. E. refractory must be used to give long life.

Monolithic Lining

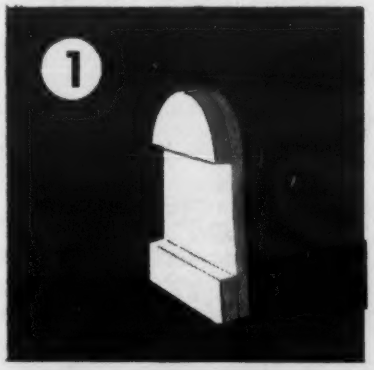
A monolithic lining for a holding ladle has been found most satisfactory, particularly if metal is desulphurized in the ladle. A back up lining of brick also gives added protection. Plastic refractory should be rammed around a form to develop a dense monolithic structure between the form and the ladle shell. Form can be made of wood or metal and as strong or as light as desired. If made sturdily to withstand ramming pressure and ordinary handling, it will last almost indefinitely.

If made of wood, the form should be sheet metal covered to give a smooth surface. Drill a few vent holes in the bottom and oil surface slightly to assist in removal after the lining is rammed. Care must be taken during removal of the form to avoid cracking or pulling lining loose. If damaged, the lining is destroyed even before it is used.

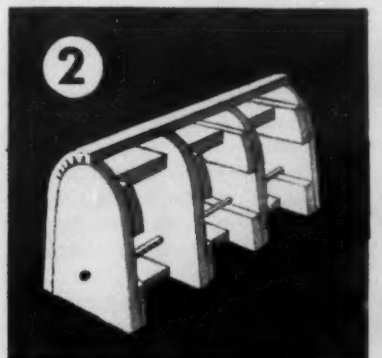
To give an idea of lining thickness normally used for various sized ladles the following are listed:

- 2-4 ton ladles – 3-1/2 to 5 in.
- 5-7 ton ladles – 5 to 7 in.
- 8-10 ton ladles – 8 to 10 in.

how to build a ladle form—8 steps

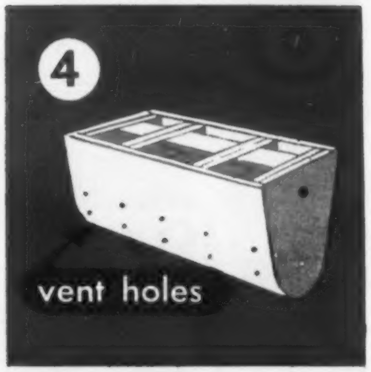


Contour of ladle lining form based on 1-in. ribs reinforced by cleats across top and bottom. For most forms, 4 ribs will give adequate support.

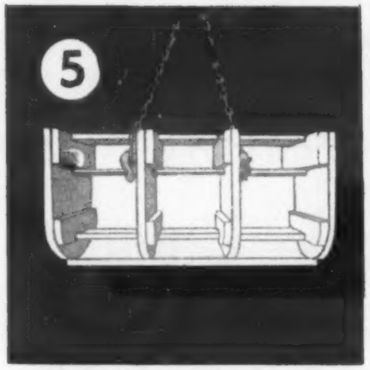


Ribs set 12-16 in. apart to resist pressure of rammed refractory. Structure may be nailed or screwed together for more durable, sturdy form.

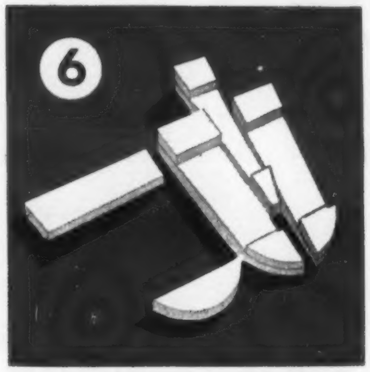
One-inch siding covers ribs. Splices may be caved in by pressure of rammed lining. Narrow strips dressed down to smooth turn over bottom.



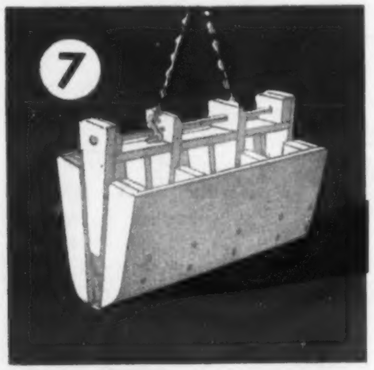
Sheet iron nailed over outside of form gives it smooth finish and makes removal easy. Vent holes along bottom prevent sucking out of lining.



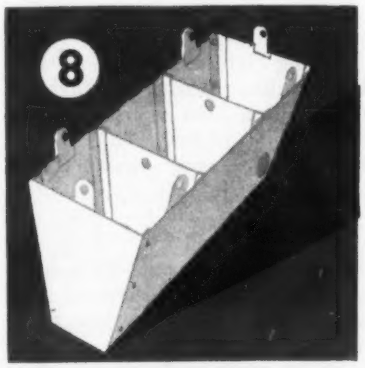
Strong pipe or rod put into form under cross braces for attaching to hoist when form is removed from ladle. Form should be lifted straight up.



Three-section rib collapsible form used in crowded ladle areas; center section pulled up and out, side sections are pulled away from ladle lining.



Complete collapsible form is built on series of 3-section ribs. Braces, metal sheathing, vent holes, and pipe for lifting same as in solid form.



Collapsible steel form with angle irons welded to end plates. To prevent sides caving in, steel-plate ribs slide in angle iron brackets.

These plastic linings may also have a 2-1/2-in. thick brick back up lining against the shell. All dimensions are approximate and depend upon metal temperature and tonnages poured.

Ramming can be done best with an air hammer to develop a uniform, dense lining having no cracks or flaws where metal or slag may penetrate. The refractory should be workable, but should not "crawl" when rammed. If an air rammer is not available, a hand tamper or mallet may be used to pound the material into place. If a form is not used, care must be taken to avoid forming laminations parallel to the ladle shell.

When no form is used ramming must be done perpendicular to the shell. Laminations or strata may occur between consecutive layers of plastic as they are applied. If no bond has been obtained, these layers will peel off like leafs of a book causing premature failure. This condition is aggravated by the fact that plastic refractory usually must be wetter when installed without a form to increase its plasticity; and then greater shrinkage results.

To overcome this problem, roughen or scratch the surface thoroughly after each successive layer is applied until the desired thickness is reached. A template or gauge must also be used to prevent thin spots in the lining.

Large transfer and bull ladles from 1500 to 10,000 lb capacities can be lined with plastic refractories. It is important to use a refractory which will not build up with slag nor react to form more slag. Many gray iron foundries are getting exceptionally long service from a graphite bearing plastic. The graphite prevents metal from "wetting" the lining and there is less chance of slag build-up.

Some of these plastics achieve success by being highly refractory and inert to hot metal. Others achieve equally good results by forming a glaze on the lining surface when contacted by hot metal. This glazed surface is very thin but prevents the passage of slag or metal. Behind this "skin" the remainder of the lining maintains its original composition and structure.

This glazing action is progressive. As additional material is exposed to the heat at the hot face, it too becomes glazed. This glassy surface is thin and viscous; the rate of erosion is quite slow, resulting in long service life. For ladle lips, cupola tap holes, and spouts where there is much erosion, this type plastic gives better results with its fused or glazed surface than other types with higher fusion points which "wash out" rapidly.

Slag Attack Resistance

A refractory plastic containing a high percentage of calcined grog best withstands slag and soda ash attack in desulphurizing ladles. Soda ash reacts with any free silica available in the refractory. Sodium silicates and highly corrosive fluxes are formed and rapidly erode the lining. At the same time the effectiveness of the desulphurizing agent is reduced. Grain sizing of the plastic is important to produce maximum density and prevent cracking or shrinking after being put into service. A super quality daub or wash coating is helpful in sealing any hair line cracks which may develop during drying and preheating.

This wash coating should provide a highly refractory surface which is resistant to slag attack. It should not be "wetted" by the slag and metal, thus preventing any slag build up on the lining. The wash should be air setting to give a smooth, hard skin which will seal the lining and not crumble or fall off.

A word of caution. Be sure that the monolithic lining is *thoroughly dried* and the ladle preheated to

CHEMICAL AND PHYSICAL PROPERTIES OF FIRE CLAY BRICK

	Typical High Duty Fire Clay Brick	Typical Super Duty Fire Clay Brick
Silica — SiO_2	54.10	52.00
Alumina — Al_2O_3	40.70	42.70
Iron Oxide — Fe_2O_3	1.72	1.56
Titania — TiO_2	1.50	1.97
Lime — CaO	0.30	0.48
Magnesia — MgO	0.50	0.20
Alkalies — Na_2O&K_2O	0.84	0.62
P. C. E.*	Cone 31-32½	Cone 33-34
Fushion Point (Approx.)	3050-3180 F.	3190-3250 F.
Deformation under load	4%	Less than 1%
Reheat change	+0.1%	Negligible
Panel Spalling loss	10-15%	—4%
Porosity	15%	10%
Modulus of Rupture	900 psi	1100 psi

*P.C.E. = Pyrometric Cone Equivalent

a red heat before applying the wash coating. You can then be sure that no moisture is sealed in the lining; and if any shrinkage cracks occur, they will be sealed.

Forehearth ladle lids may be laid up with brick, rammed with plastic, or poured from a castable refractory. Lids have no direct contact with metal, so the primary requirements are resistance to temperature and thermal spalling. Lugs or gaggers should be placed in the lid to support the rammed plastic or the castable. Gaggers may be bolts, screws, rods, wires, or angles, running through the lid or welded to it. They should extend to within 1-2 in. of the hot face of the refractory, depending on its total thickness. Ample strength is provided when placed on 6-8 in. centers.

Hand Ladles

In the smaller pouring ladles and hand ladles, refractory linings are subjected to considerable abuse. Although metal temperatures are lower in these small ladles, there is usually considerable spalling caused by rapid heating and cooling throughout the day. Also, hand ladles receive extensive mechanical shock from rough handling. Consequently, these ladles are usually relined after every heat with a cheap clay, or sand-clay mixture to save money. It would be worth investigating to see if a higher quality refractory lining might pay off in better quality castings and less scrap. Better refractories may eliminate slag buildup and thereby extend the service life many times that obtained with a cheap refractory lining.

When tapping metal into a ladle, small bits of slag and other foreign materials will float on the iron. These particles will be poured into the mold unless extreme care is exerted. When found in a half finished casting in the machine shop, these slag inclusions represent a considerable loss.

Pouring and Bottom Tile

By using ladle pouring brick—fire clay shapes in the form of half cylinders of varying diameters and lengths—the foundryman can secure the benefits of bottom pour ladles from either crane, bull or hand ladles. The ladle pouring brick is pressed into the side of the ladle lining 1/4- to 1/2-in. while the plastic is still damp. Lower end of the brick is placed about 2-in. above the bottom. Ladle is dried in the usual manner. When pouring, clean iron passes up through semi-circular passageway formed by the brick, and the slag remains in the ladle. Since tile diameters are graduated according to ladle sizes, proper selection permits adequate pouring rates.

Diameter sizes or lengths may be changed according to specific requirements for certain applications. Such tile are used principally in gray iron foundries where temperatures are not too high. In steel foundries, they will not withstand the high temperatures and iron oxide encountered, so freezing usually occurs in the spout.

Ladle bottom tile are another specialty fire clay refractory used in ladles. These round disks are used on the ladle bottom in place of fire clay brick, which are hard to fit, have joints, or may be difficult to dry.

"Boiling" may occur in the bottom of a ladle if it is not thoroughly dried out. This reaction leads to inverse chills in castings and slag in the metal. Ladle bottom tile are easy to install and economical to use. A cushion of clay is spread over the bottom and the proper size ladle bottom tile placed directly over it. Line the sides in usual manner, dry thoroughly, and the ladle is ready to use. The tile forms a solid bottom with no joints and little chance of a bottom spill. Bottom is dry so there is no boiling.

Acid Lining

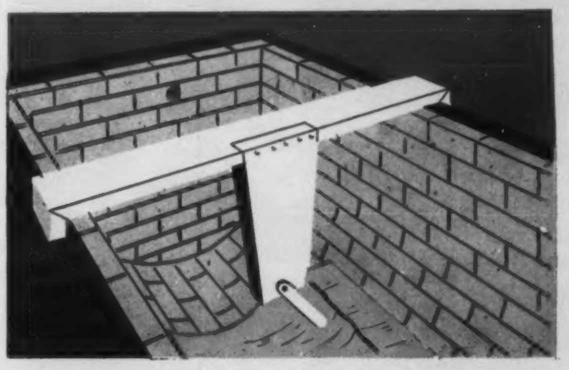
In malleable foundries, higher temperatures are common and the metal is often oxidizing. By using an acid or siliceous type refractory lining the high heat will slightly vitrify the lining surface, so it remains unaffected by metal or slag. The highly siliceous ramming mix should be tempered with water to the consistency of damp molding sand. Ram the lining as dense as possible to eliminate soft spots and cracks. As the ladle is brought up to operating temperature, the silica expansion eliminates shrinkage cracks.

This same type of lining works well in ladles handling acid elec-

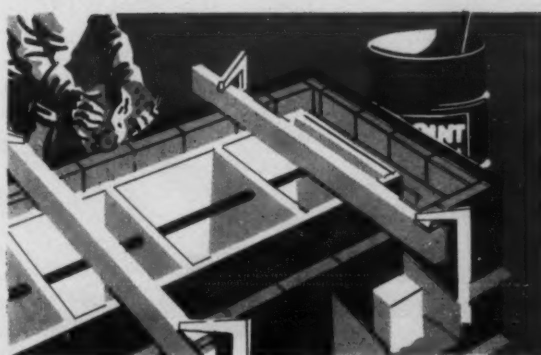
how to use the ladle form—6 steps

1 Ladle bottom rammed after the brick lining is completed. Ramming follows contour of bottom radius of ladle.

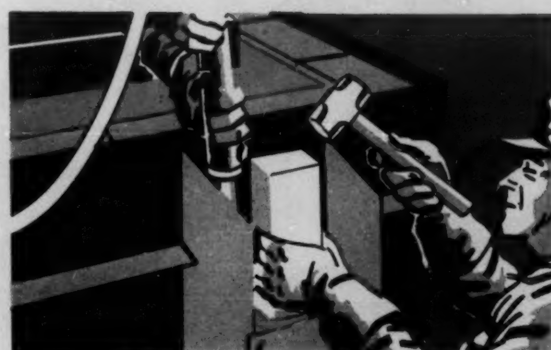
2 Bottom contour gauge checks thickness and shape of the ladle bottom; low spots are filled, and high points cut down.

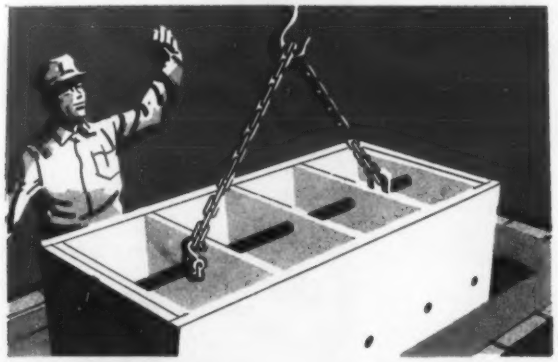


3 Ladle form positioned to give equal lining thickness to all 4 sides. Ramming is started and complete circle is made to bring lining to uniform density.

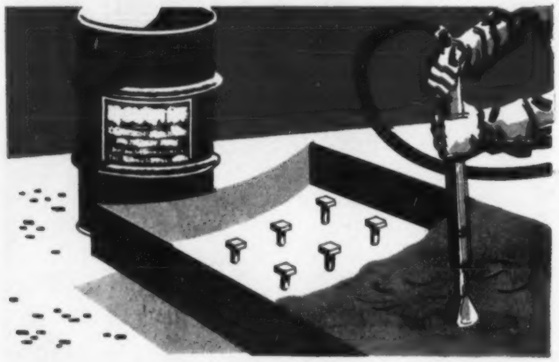


4 Ramming is done after ladle sides completed. Top of spout tapped because form forced up from pressure of ramming.



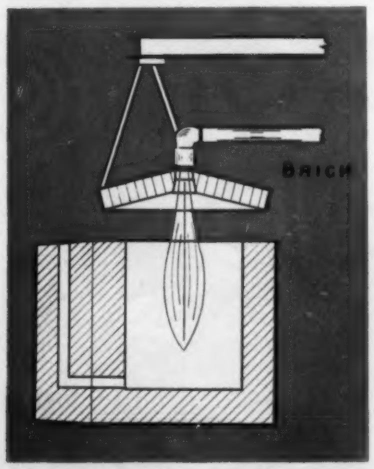


5 Ladle form removed when ramming complete. Vent holes opened; ladle form rapped to loosen it for easy removal.



6 Anchor bolts or bent rods welded in ladle cover to hold refractory lining. Anchors should be 1 in. less thick than lining.

tric steel. Metal temperatures may reach 3200-3250 F and this siliceous refractory will give safe, dependable service. Frequently a grain sized quartz ganister is added to make a 50-50 mix. This proportion may be varied 10 per cent either way depending upon the individual factors, such as ladle size, density required, mechanical erosion, etc.



Gas flame dries ladle lining.

Grain-sized ganisters are those having the fines screened out. The resulting product helps obtain maximum densities by forming a matrix for the fine grained siliceous mix. Also, most of the impurities in the ganister are in the fines. By removing them, the P. C. E. is improved.

Ladle Drying

Regardless of what material is used as a ladle lining refractory, care in making and bringing it safely up to operating temperatures are vitally important. Whenever mud or rammed, monolithic linings are used, ladle shell should be vented to permit moisture to escape during the drying period. Without vent holes, the time required to drive out all entrapped water is prohibitive. When the lining is over 4-in. thick, moisture may be driven back against shell during drying where it remains with no escape route. Then when ladle is put into service, vapor forms and causes spalling and rupture of the refractory lining.

continued on page 120

1958 Transactions Preview

AMERICAN FOUNDRYMEN'S SOCIETY – PREPRINT NO. 58-57
This paper has been approved for presentation at the 62nd Annual Meeting of the American Foundrymen's Society, to be held in Cleveland, Ohio, May 19-23, 1958. The Society reserves all rights for publication either prior to or subsequent to presentation, and is not responsible for statements or opinions advanced herein.
WRITTEN DISCUSSION IS SOLICITED

Risering of Gray Iron Castings

AFS Gray Iron Division Research Report

By

J. F. Wallace* and E. B. Evans*

ABSTRACT

The technical literature on the risering of gray iron was critically reviewed and the pertinent variables evaluated. A recommended risering procedure for gray iron castings is advanced based on available data and some original concepts and calculations.

INTRODUCTION

This report describes the results of a critical review and analysis of the technical literature on the risering of gray iron castings. The work was conducted under the sponsorship of the AFS Gray Iron Division Research Committee to utilize information in the available literature to establish an acceptable and readily applicable gating and risering procedure for gray iron.

An initial report on this project was submitted on the gating of gray iron castings[1] and a subsequent article on the problem of mold wall movement.[2] The risering procedures recommended herein are designed to produce a casting true-to-pattern and free of all shrinkage porosity.

The scientific employment of risers on castings is one of the more important technical subjects involved in the manufacture of sound castings. Starting with the work of Chvorinov,[3] several recent articles have treated this subject in considerable detail. Caine[4] reviewed the basic variables and fundamental approach to the problem. Adams and Taylor[5,6] have described a quantitative approach for determining riser sizes based on metal, mold, and heat transfer considerations.

Other articles have related this information to specific metals and have modified the approach to comply with empirical measurements. Caine[7] has considered steel more directly. The investigators at the Naval Research Laboratory have written a number of articles[8-13] on risering steel and nodular iron that include considerable experimental work to establish the riser sizes accurately for several casting conditions and greatly simplify the mechanics of riser size determination. Shnay and Gertsman,[14] Shnay,[15] and Flinn, Reece and Spindler[16] reported on the selection of riser size and feeding distance for nodular iron castings.

The literature also contains numerous articles on the risering of gray iron castings. However, these articles are not as specific in recommending definite riser dimensions and locations as is the case for steel and nodular iron. A series of six progress reports by Taylor et al.[17] are reported in separate publications and the Transactions of AFS.

This series of articles covers work sponsored by the Research Committee of the Gray Iron Division and provides much basic information concerning the solidification behavior, liquid and solid contraction, and mold wall movement relevant to risering gray iron castings. Dunphy, Ackerlind and Pellini[18] also discuss some of the feeding problems on gray iron castings in another publication.

The adequate risering of all metals involves two primary considerations: first, the selection of a riser of sufficient size to compensate for liquid and solidification contraction and any mold wall movement; and second, the positioning of this riser or risers so that liquid feed metal from the riser is able to reach all parts of the casting. Failure to employ a riser where needed, or to use one of sufficient size, can produce a large gross shrinkage cavity.

In gray iron, a narrow, deep surface depression called a draw, or a shallow surface depression referred to as a sink, may result rather than gross internal shrinkage. Improper riser location or an insufficient number of risers in a gray iron casting will produce a finely dispersed shrinkage or microporosity in some sections.

SOLIDIFICATION OF GRAY IRON

The risering of a metal, particularly the problem of riser location, is dependent on the mode of solidification. It is necessary to understand this mechanism so that the pertinent factors influencing the selection of adequate risers may be controlled. The mode of

*Assoc. Prof. and Asst. Prof., Department of Metallurgical Engineering, Case Institute of Technology, Cleveland.

Progress Report on research project sponsored by the Research Committee of the Gray Iron Division of AFS. Members of the Committee are: J. S. Vanick *Chairman*, R. A. Clark, W. W. Edens, D. Marsh, R. Gregg, K. L. Landgrebe, O. Meriwether, G. P. Phillips, J. E. Rehder, G. E. Tait, and C. F. Walton.

solidification of gray iron has also been investigated to a considerable extent.[17, 19-22]

The mechanism of solidification of gray iron depends upon several factors, including composition, cooling rate, inoculants and melting variables. In the absence of mottling, hypoeutectic gray irons start to solidify as austenitic dendrites and complete solidification as eutectic cells of austenite and graphite flakes within the eutectic temperature range. The primary austenitic dendrites always solidify with a contraction, but the eutectic cells, because of the low density of the graphite, may solidify with an expansion. The composition of the iron, melting practice and inoculation determine the relative amounts of primary austenite and eutectic which, in turn, determine the resulting expansion (or contraction) of the eutectic.

Inoculation of the iron can also influence the relative amount of eutectic expansion.[17] The composition will also affect the freezing temperature range of the iron; the lower the carbon equivalent of the iron, the greater the freezing temperature range and the more mushy the solidification. This latter fact, in conjunction with the greater solidification shrinkage experienced with lower carbon equivalent irons, generally results in more difficult feeding problems compared to the softer eutectic gray irons.

Problem of Microporosity

Micro or dispersed porosity has been a consistent complaint of gray iron foundrymen. This defect frequently occurs under risers and in heavy sections of the castings. While some of the "open grain" referred to in these locations may be the result of the coarser flake graphite, this rough appearance is frequently dispersed internal porosity. There appear to be at least two causes for this defect: 1) an inadequate feeding distance of the risers employed; 2) the liquid and solidification contraction of a high phosphorus constituent which occurs after solidification of the graphite-austenite eutectic.

Internal porosity is only produced in the first case when the riser size or location is inadequate, and the expansion accompanying the formation of the austenite-graphite eutectic is not sufficient to compensate for the liquid and the primary-austenite contractions which occur during solidification.

The marked effect of phosphorus on the manner in which gray iron solidifies has been demonstrated by numerous investigators.[20-25] Phosphorus segregates between the eutectic cells into a low-melting-temperature liquid in the form of a ternary (or pseudobinary) austenite-graphite-iron phosphide eutectic that solidifies at approximately 1700 F, which is 300 F. lower than the graphite-austenite eutectic (about 2050 F). This ternary eutectic exists as a liquid film around the cells during the solidification of the austenite-graphite eutectic.

If the amount of this latter eutectic solidification is sufficient, the resulting expansion may force some of this high-phosphorus liquid through open channels to the outside surface as exuded beads. The austenite-Fe_3P-graphite eutectic remains liquid for a considerable period, or until the casting has cooled from about 2050 to 1700 F, before it solidifies. It has been indicated that this ternary eutectic liquid contracts during cooling and also contracts during solidification.

In addition, gray irons with a large percentage of phosphorus solidify with a large number of fine eutectic cells, and thereby produce numerous fine channels throughout the cross section of the casting. The result is that the solidifying ternary eutectic of austenite-Fe_3P-graphite produces a contraction under circumstances that interfere with feeding to complete soundness, and may produce dispersed porosity, particularly in sections adjacent to risers.

It has been shown that the existence of this ternary phosphorus eutectic can produce shrinkage porosity in: a) castings that would not normally require risers because of sufficient austenite-graphite eutectic expansion[25] and b) castings of a lower carbon content, even when risers that are normally considered adequate are employed.[23, 24] There is some evidence that the tendency for microporosity to occur is increased by alloy content.[24]

The prevention of internal porosity in gray iron is favored by a phosphorous content below 0.10 per cent under most circumstances, and such factors as steep thermal gradients, large eutectic cells, and less mushy solidification. The lower phosphorus contents reduce the amount of ternary eutectic that solidifies at this low temperature where feeding is not feasible. More open-feed channels from risers are provided by steeper thermal gradients, larger eutectic cells, and solid skin solidification. It is reported that these open-feed channels are favored by low pouring temperature, high furnace temperature and no inoculation.[25]

Effect of Mold Materials on Risering

The combination of high pouring temperature and mushy mode of solidification that occurs in the casting of gray iron can produce considerable variation in final dimensions, depending on the type of molding materials. The high pouring temperature produces considerable thermal expansion in the sand mold wall and the mushy solidification mechanism allows the casting to follow the sand mold wall throughout much of the solidification period.

The influence of green and dry sand molds on mold wall movement and the riser requirements in these cases were discussed by the authors in a recent article.[2] This work indicated the influence of numerous molding and metal variables on the amount of mold wall movement obtained. It is apparent that negligible movement is experienced in dry core and CO_2 sand molds, but that considerable outward movement of the mold wall is found in some cases with green sand molds.

In the latter case, the mold wall expansion increased with higher moisture and clay content of the sand, higher pouring temperature, and higher graphitic carbon of the metal. Increased mold hardness, additions of sea coal or other carbonaceous material to the sand, and smaller size castings reduce this movement.

This variation in mold wall movement influences riser requirement since any outward movement of the mold wall will increase the size of the mold cavity after the casting has been filled with molten iron. The selection of riser dimensions, then, depends on

the type of molds employed, methods of ramming and grades of iron poured in each foundry.

A volumetric mold cavity expansion of about 1.5 per cent is generally obtained in a good quality green sand mold, and negligible expansion in small dry sand molds. Mold expansion can be very severe in some types of green sand molds. The experimental determination of the actual expansion encountered in each foundry appears advisable.[2]

Data are available to demonstrate that core expansion in heavily cored castings and the inward movement of mold walls in larger castings produced in dry sand molds can greatly affect riser requirements. Some foundries have been able to produce large high strength gray iron castings in dry sand molds without risers; other foundries can successfully reduce riser requirements for some gray iron castings where extensive coring is employed.

These castings have been made under conditions and from analyses that definitely exhibit liquid and solidification contraction. Experimental data are available for large Diesel engine blocks[26] that could be cast sound without risers because of the heavy coring. The core boxes in this case were made with a standard rather than a shrink rule, indicating that the cores had enlarged sufficiently from thermal expansion to offset liquid and solidification contraction and compensate for solid thermal contraction.

Although insufficient data are available to predict quantitatively the amount of contraction of the mold cavity that occurs under specific conditions, it is evident that this contraction is increased by certain variables in dry sand molds including:

1) Larger casting section size
2) Harder, more rigid molds[27]
3) Lower carbon equivalent irons with their increased solidification contraction and more mushy solidification
4) Higher pouring temperatures
5) Increased core volume

The larger section sizes with higher volume to surface area $\frac{V}{SA}$ ratios increase inward sand expansion in dry sand molds because the longer solidification times result in greater heating of the sand and deeper heat penetration into the sand.[28]

A schematic plot of the influence of section size or $\frac{V}{SA}$ ratio on the inward sand movement for dry sand molds is shown in Fig. 1. These results have been based on the work of Gittus,[29] performed with a 4.1 per cent carbon-equivalent iron cast in dry sand as a 4 in. diameter by 6 in. long cylinder. The movement of the casting after pouring was a two-stage process, and is plotted as Curve No. I of Fig. 1.

In the first stage immediately after pouring (AB in Fig. 1), the mold cavity contracted due to the inward expansion of the sand into the fluid casting and continued to contract until what has been interpreted to be the end of primary austenitic solidification (Point B). At this point, marking the beginning of stage No. 2, a reversal in the direction of casting movement occurred as eutectic solidification started. The casting continue to expand until it was completely solid (Point C). However, the casting expansion (vertical height of BC) cannot be entirely the result of expansion arising from graphite precipitation during eutectic solidification since eutectic expansion for this iron is 0.5 per cent or smaller,[17] whereas the mold dilation amounts to a 1.6 per cent increase in volume.

The eutectic expansion will fill any shrinkage cavities resulting from the primary austenite solidification before enlarging the mold cavity, particularly during the early periods of eutectic solidification. Such phenomena as gas evolution or thermal expansion into a comparatively weak backing sand layer could account for this enlargement of the mold cavity. Assuming

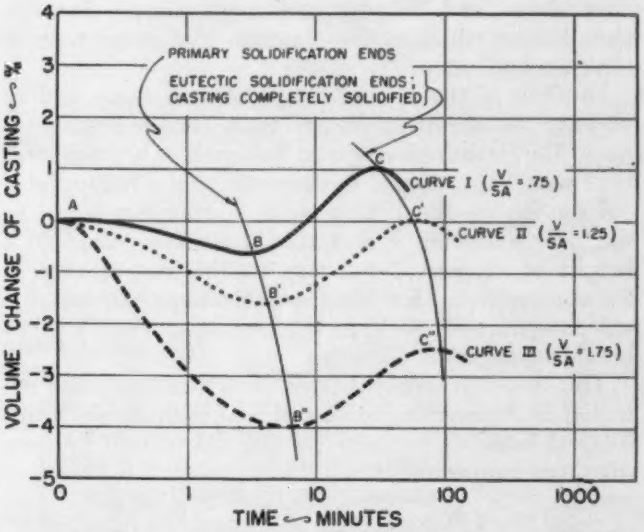


Fig. 1—Casting movement during solidification of gray iron in dry sand. (Curve I after Gittus.)

that the mold dilation (vertical height BC) is reasonably constant for a given sand, the influence of the $\frac{V}{SA}$ ratio is depicted in Fig. 1.

Curve II corresponds to a case where the increase in inward expansion caused by greater heating of the sand results in a net casting movement (mold wall movement prior to solidification) of zero. Curve III illustrates the case where the net effect is a volume contraction of 2.5 per cent, which is equal to the assumed sum of liquid contraction (2 per cent) and solidification contraction (0.5 per cent)[17] for a carbon-equivalent iron of 4.1. When this occurs in practice, no risering is required. As discussed previously, the metal temperature, composition, and mold rigidity can either increase or decrease the amount of this mold cavity contraction.

Selection of Riser Size

It is evident from the preceding paragraphs that the risering of gray iron depends upon many variables, and that special considerations, such as the effect of phosphorus on microporosity and the presence of large cores and heavy sections in dry sand molds, may be of great importance in establishing risering. Assuming that the phosphorus content is low enough to prevent microporosity difficulties and that core expansion and inward mold wall movement do not apply, it is possible to generalize on the risering of gray iron castings.

The variables that must be considered in this general case are: type of mold, composition of the

metal, and dimensions of the casting. A standard amount of mold wall expansion is assumed for a good quality green sand mold, and a standard amount of liquid contraction is based on a reasonable amount of superheat at the pouring temperature. Since riser size depends on the amount of liquid and solidification contraction and mold wall movement, it is possible to make some computations of riser requirements.

Considerable data are available[11-16] on the relative dimensions of risers. This work indicates that risers should be cylindrical with the height of efficient, economic risers equal to ½ to 1 riser diameter. General riser shape and foundry conditions usually favor a riser height equal to the diameter and some type of top riser insulation.

In view of the special shape of side risers and to prevent the shrinkage cavity from entering the riser neck, the preferred shape in this case is a cylindrical riser with height equal to diameter, and a hemispherical section on the bottom with a diameter equal to the riser diameter. Risers should always extend to a height of at least 1 in. over the highest section of the casting being fed after solidification. Accordingly, all computations will be based on a riser with a height equal to the diameter.

The two-base compositions shown below were selected as representative of soft and high strength unalloyed irons to be used for the calculation of riser diameter requirements.

Type of Iron	%C	%Si	%P	%S	%Mn
Soft Gray Iron	3.5	2.2	0.05	0.10	0.60
High Strength Gray Iron	3.0	1.5	0.05	0.10	0.80

The amount of liquid contraction, volume increase from mold wall movement in green sand molds, and solidification contraction estimated for these two compositions are:

Type of Iron	% Liquid Cont.	% Mold Wall Movement (Green Sand)	% Mold Wall Movement (Dry Sand)	% Solidification Cont.
Soft Gray Iron	2.0	1.5	0	0
High Strength Gray Iron	2.0	1.5	0	1.4

The liquid contraction allows for about 250 F superheat. A review of the published data[17] indicates a wide divergence in liquid contraction values; 0.8 per cent per 100 F was chosen as an average figure. The value of 1.5 per cent volume expansion from mold wall movement in green sand molds was selected as an average value based on a review of the literature on this subject, although this value will vary widely with some sand properties and ingredients. Mold wall movement in dry sand molds is considered negligible. The solidification contraction quantities were obtained from Taylor's work[17] on this subject. All of the contraction or expansion figures can be adjusted to comply with individual foundry conditions.

In view of the lack of substantiated data on the size of risers for gray iron castings of known shape, it was necessary to adopt a theoretical approach to the problem. The basic work of Caine[4] is applicable to all metals and develops the equation:

$$x = \frac{a}{y-b} + c \qquad \text{Eq. (1)}$$

where: $x = \frac{V_R}{V_C} = \frac{\text{Volume Casting}}{\text{Volume Riser}}$

$$y = \frac{\frac{SA_C}{V_C}}{\frac{SA_R}{V_R}} \quad \frac{\frac{\text{Surface Area Casting}}{\text{Volume Casting}}}{\frac{\text{Surface Area Riser}}{\text{Volume Riser}}} \quad \text{or Freezing Ratio}$$

b = fractional solidification shrinkage
c = factor comparing heat transfer of media surrounding riser and casting and is unity for similar molding materials
a = adjustable constant

By comparing the reported data for nodular iron and steel,[11, 12] utilizing the simplifying assumptions of Caine[4] and NRL,[11] and assuming cylindrical risers with a height equal to diameter it is possible to simplify equation 1 to the following:

$$SA_C = \frac{125}{\frac{D}{b \cdot V_C} - \frac{\pi}{4D^2}} = \frac{125}{\frac{D}{b \cdot V_C} - \frac{1.275}{D^2}} \qquad \text{Eq. 2}$$

where: D = diameter of riser
b = fractional solidification

This equation can be solved for different values of *b* to obtain a relationship between the surface area of the casting (SA_C) volume of the casting (V_C), and diameter of the cylindrical riser (D), where the height of the riser is equal to the diameter. Then, adjustment of the D values is possible to allow for liquid contraction in both the mold and riser cavities. The authors are indebted to Harrish Merchant for this approach as developed during separate work at Case.

The values selected for mold wall movement and solidification contraction for the two gray irons were added to obtain *b* in Equation 2. This permitted the establishment of the numerical relationships between V_C, SA_C, and D in this equation. The riser diameter was then adjusted to allow for the 2 per cent liquid contraction in the volume of the riser and casting to yield a final value of D. This last calculation was rather complicated since unity riser diameters were desired. These computations were made by the staff members of the Computing Center at Case.

The results of these calculations have been plotted in Fig. 2 for high strength iron cast in green sand molds, and in Fig. 3 for high strength iron in dry sand and soft gray iron in green sand. Soft gray iron in dry sand will either require no riser or only a small shrink bob that is 2 to 4 per cent of the volume of the casting. Some limited data available to the authors on acceptable risering practice agree closely with the riser sizes specified by Figs. 2 and 3.

When multiple risers are required for a given casting, the riser size determination is based only on the surface area and volume of that portion of the casting fed by this riser. Uniform sectioned castings are generally divided into equal portions for this computation with one riser for each section. When risers are determined for irregularly shaped castings, however, the casting portions and resulting risers may be of different sizes.

Selection of Riser Necks

The method of attaching the riser to the casting, i.e., the riser neck, should be considered in any risering practice. The riser neck is somewhat smaller than the riser so that the neck will solidify slightly before the riser and locate the shrinkage cavity wholly within the riser. Since the riser neck must not solidify too soon, the dimensions are dependent on the length of the neck. Frequent use is made of thin, strong ceramic or core material for necks of a small cross-sectional area—called Washburn cores—to facilitate riser removal.

The literature contains several articles on this subject; some reports are empirical[30-33] and others, primarily theoretical, are based on a consideration of heat flow.[34, 35] Except for some small differences in the recommendations for the length of the riser neck, there is fairly good agreement. The following general recommendations can be made from these data:

1) The riser neck should be round where possible. This is usually feasible except for side risers on plate castings.
2) The length of the riser neck is determined to some extent by the size of riser, shape of casting, and type of molding or core material—the shorter this riser neck, the smaller the cross-sectional area of the neck. The riser neck should never exceed one-half the riser diameter, if at all feasible.
3) Riser necks may have either a straight or a tapered (notched) section although sharp corners can result in sand erosion problems when the casting is gated into the riser.
4) Riser necks attached to plate sections should have a smaller thickness than that of the casting.
5) The riser neck should be positioned near the bottom of a side riser. In the case of the preferred type of cylindrical side riser with a hemispherical bottom, the center of the riser neck should be located a distance of D from the bottom of the riser. It must be remembered, however, that the top of the riser should be at least 1 in. over the highest part of the section of the casting being fed by this riser after solidification.

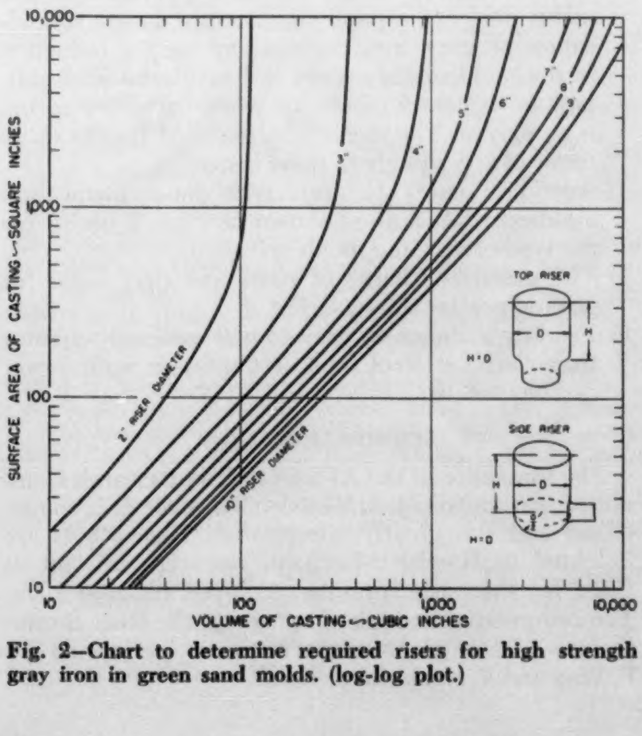


Fig. 2—Chart to determine required risers for high strength gray iron in green sand molds. (log-log plot.)

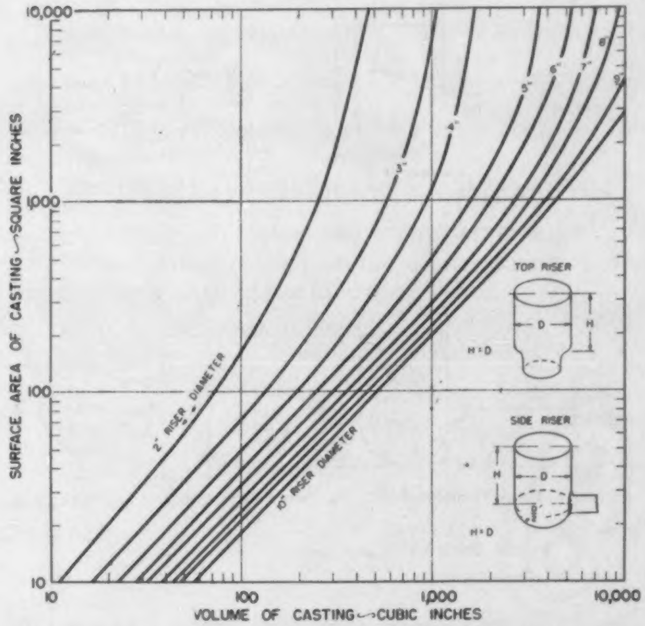


Fig. 3—Chart to determine required risers for high strength gray iron in dry sand molds and soft gray iron in green sand molds. (log-log plot.)

The application of these principles to practice leads to recommended riser neck sizes for three specific cases: 1) the general type of side riser; 2) the side riser feeding a plate-type casting; and 3) the top riser. The recommendations of each publication and an individual consideration of these three specific cases are contained in the Appendix.

These considerations result in the riser neck limitations and equations for determining the length and cross section of the neck for the three cases shown in Fig. 4. This figure also shows the preferred side and top riser dimensions previously discussed. A graphical method of determining riser neck dimensions from these equations is feasible for definite lengths of neck and riser diameters, as shown for each case in Fig. 5.

GENERAL CONSIDERATIONS OF RISERING

The location of risers in gray iron castings conforms to the general risering principles for all metals. Risers are attached to heavy sections of the casting or the last portion of a casting to solidify. If a casting contains more than one heavy section joined by lighter sections, then a separate riser is required for each heavy portion. The feeding distance of risers can be increased by increasing the thermal gradients within the casting so that the portions remote from the riser are the coldest and the risers are the hottest. These thermal gradients can be increased by:

1) The use of chills, although they must be used cautiously to avoid mottling
2) Insulation, and the addition of exothermic material to risers
3) Padding of casting sections toward risers (little used in gray iron)
4) Gating into the risers.

Gating is more convenient into side than top risers.

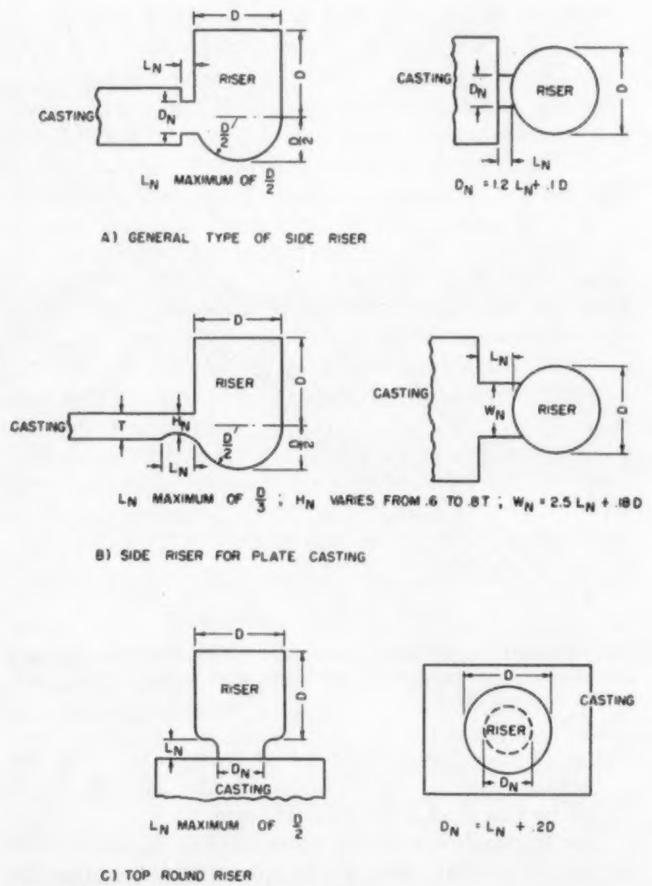


Fig. 4—Schematic riser neck dimensions.

A slow pouring rate will produce greater thermal gradients than a rapid pouring rate. The stategic location of gates in light sections and a controlled pouring rate have been employed in lieu of risers for some softer irons. These principles of risering are discussed in the more general articles.[5, 6, 7, 28, 32, 36]

Quantitative data on the feeding distance of adequate risers in uniform sections, as reported for steel and nodular iron, [8-16] are not available in the literature for gray iron. Solidification studies demonstrate that the greater solidification temperature range of the lower carbon equivalent, higher strength gray irons will result in shorter feeding distances than for softer and nodular iron,[8-16] are not available in the literature irons. Not much feeding can be expected in any gray iron after considerable eutectic solidification.

When the eutectic solidifies with an expansion, as is generally the case, a self-feeding condition occurs and no additional feed metal is required from the riser. This expansion can even compensate for some solidification contraction that has resulted from the formation of primary austenitic dendrites. In the latter case, the feed channels to the riser need only be passable to liquid feed metal during the initial stages of solidification of a high strength gray iron. Under these circumstances, it is not surprising that Pellini[36] states that the feeding distance of gray iron in uniform sections is essentially unlimited, provided that risers of adequate size are employed.

It does appear that feeding distances are relatively long in gray iron provided that the eutectic expands during solidification and the iron is not strongly hypoeutectic. If these latter conditions are satisfied, feeding distances in uniform sections should be appreciably greater than for steel,[8-11] although the actual length will decrease with decreasing carbon content.

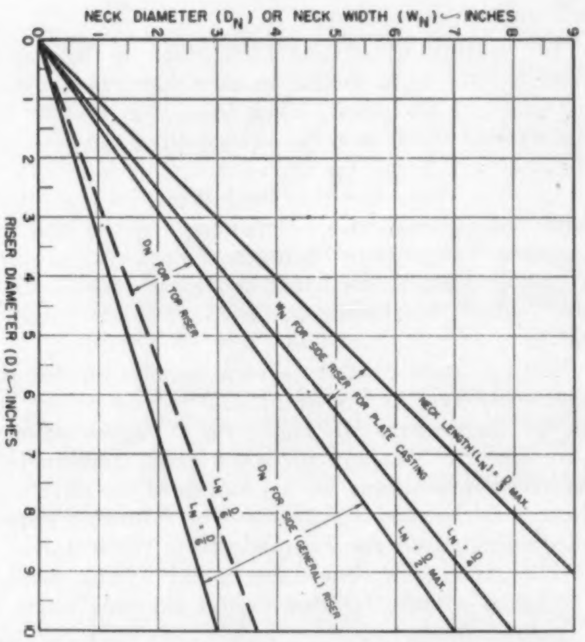


Fig. 5—Riser neck dimensions as a function of riser diameter.

CONCLUSIONS

The adequate risering of gray iron castings is a complex problem because of the many variables influencing the melting, casting, and solidification of gray iron in sand molds. It is possible, however, to make several statements concerning good risering practice for general application:

1) A low phosphorous content (below 0.10 per cent) is desirable to eliminate microporosity.
2) Adequate riser size must be selected to compensate for liquid and solidification contraction in all molds, and also for some mold cavity enlargement in green sand molds.
3) The mold cavity in dry sand, core, or CO_2 process molds does not expand significantly during solidification of gray iron castings; in fact, a reduction in the mold cavity occurs in heavy sectioned castings in dry sand molds, or when extensive coring is employed. The size of the required risers can be reduced accordingly in these instances.
4) Adequate risers for use with most metal and molding practices are shown in Figs. 2 and 3 for the type of iron and molds specified.
5) The preferred shapes of risers and riser necks for general use are shown in Fig. 4.
6) Feeding distance in gray iron is generally greater than that for steel, and it decreases with lower carbon content.

ACKNOWLEDGMENT

The assistance of the AFS Gray Iron Research Committee, particularly J. S. Vanick, *Chairman*, is acknowledged and was greatly appreciated. The authors are indebted to Harrish Merchant, research assistant at Case, for the basic formula employed for riser sizes. The computations required to convert the basic formula into usable graphical forms were performed by F. Way and P. Nacktsheim.

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APPENDIX ON RISER NECK DIMENSIONS

A summary of the results from the practical and theoretical investigations on the dimensioning of riser necks is contained in the following Table.

Type of Riser	Length of Riser Neck, in.	Dimensions of Neck, in.
Side	–	D width; $\frac{T}{2}$ thickness
Side & Top	–	Area of neck (sq. in.) = $\frac{D}{2}$ or D depending on riser size.
Side	$\frac{D}{3}$	D width; $\frac{3T}{4}$ thickness
Side	$\frac{D}{2}$	$\frac{D}{2}$ (round neck)
Top	short as possible	$\frac{D}{2}$ (round neck)
Top	$\frac{D}{2}$	$\frac{2D}{3}$ (round neck)
Side	$\frac{D}{6 \text{ to } 9}$	Width + thickness = $\frac{D}{6}$
Top	$\frac{D}{6}$	$\frac{D}{3}$ (round neck)

D = diameter of riser (in.); T = thickness of casting (in.)

Specific recommendations for dimensions of riser necks for the general type of side riser, side risers for plate castings, and top risers are discussed below:

I. General Side Riser—Fig. 4A
   a) Round neck preferred, either smooth or tapered
   b) Length of neck L_N as short as feasible but not greater than one-half the diameter of the riser, D
   c) Diameter of riser neck, D_N is expressed as $D_N = 1.2\ L_N + 0.1\ D$

II. Side Risers for Plate Castings – Fig. 4B
   a) The riser neck, L_N, is as short as feasible but never longer than $\frac{D}{3}$.
   b) The preferred shape of the riser neck is rectangular with the height and width both dependent on the length of the riser neck. The height of the neck at the thinnest section increases from 0.6T to 0.8T (where T is the thickness of the plate casting) as the length of the riser neck increases from $\frac{D}{10}$ (or smaller) to $\frac{D}{3}$. The width of the riser neck at the thinnest section is expressed as:
   $$W_N = 2.5\ L_N + 0.18\ D$$
   where: W_N = width of riser neck in inches.

III. Top Round Risers – Fig. 4C
   a) The necks for top round risers should be located as close to the casting as feasible and the riser neck length should never exceed $\frac{D}{2}$.
   b) A round riser neck is preferred with a diameter, D_N, expressed as:
   $$D_N = L_N + 0.2\ D.$$

AMERICAN FOUNDRYMEN'S SOCIETY – PREPRINT NO. 58-2
This paper has been approved for presentation at the 62nd Annual Meeting of the American Foundrymen's Society, to be held in Cleveland, Ohio, May 19-23, 1958. The Society reserves all rights for publication either prior to or subsequent to presentation, and is not responsible for statements or opinions advanced herein.
WRITTEN DISCUSSION IS SOLICITED

SOME STRUCTURAL CONSIDERATIONS IN NODULAR IRON

By

Verne Pulsifer*

ABSTRACT

A description of the solidification process of nodular iron is given with the proposal that nodules form near the liquidus in a normal nucleation process rather than near or below the solidus. This proposal is supported by several observations including studies of rapidly chilled shot. A diagram is also given which explains the mechanism and the structures resulting from the formation of magnesium sulfide in nodular iron.

The purpose of this paper is to present some new information to clarify some aspects of the mechanism of nodular iron solidification. There seems to be considerable variety of opinion regarding the sequence of events leading to the formation of nodules. The formation of nodules and other structural features will be discussed in relation to present understanding of the chemical reactions and diffusion effects.

There is no direct evidence to show precisely when nodules first form during solidification. To clarify this point, a technique of shotting the liquid metal in water was used to obtain extremely fast quenching rates. Cooling of the smallest members of the shot population required time intervals on the order of 3 sec. Comparison of the resulting shot structures allows some fairly strong conclusions to be drawn regarding the growth rate of graphite nodules.

The method of shotting was to pour a stream of iron through a moving wet cloth mesh held above or in a water bath. With an open mesh cloth, falling distances were no more than 18 in. The extinction of color of the molten metal was easily observed through the water, the larger particles requiring much longer extinction times because of the steam jacket formed around the hot metal.

The very fine shot appear to cool before the insulating layer of steam is formed. The cooling time was measured with a stop watch, measuring from the time the metal left the pouring lip to the time of color extinction in the bath. The 3-sec quenching time was associated with the fine shot whose diameters were one-half millimeter or less.

Using this technique, it was possible to quench hypoeutectic gray iron sufficiently fast to almost completely suppress the precipitation of flake graphite. In most of the fine gray iron shot thus produced, the appearance of graphite was revealed in the microsection as small black specks.

As the size of the shot decreased, and consequently as the cooling time decreased, the size of the specks decreased until they were impossible to resolve microscopically. The structure consisted of a fine mixture of graphite, cementite, and austenite, as shown in Fig. 1. A typical analysis for the gray iron was 3.62 per cent carbon, 2.61 per cent silicon, 0.74 per cent manganese, 0.10 per cent sulfur, and 0.12 per cent phosphorus.

In nodular iron, perfectly normal nodules were present in fine shot cast from the same temperature, although they were few in number. A nodule from one of the rapidly cooled shot is shown in Fig. 2. The period between inoculation and shotting was on the order of 3 min in all cases. Therefore, the large nodules had available a maximum approximately isothermal growth period of about 3 min.

Based on the structural evidence of the presence of normal sized and spherical shaped nodules in rapidly chilled iron shot, it is concluded that the nodules form above the liquidus during this period when the melt is cooling to the pouring temperature. Such perfect nodules would not be expected to grow within the short time interval of shot quenching. In gray iron, the graphite is undercooled to a lower temperature near or below the solidus, and does not appear until after the formation of proeutectic austenite.

The nodular iron analysis was nominally 3.80 per cent carbon, 2.90 per cent silicon, and 0.65 per cent manganese, 0.010 per cent sulfur, and 0.03 per cent phosphorus. The method of inoculation was to add the magnesium alloy and the ferrosilicon to the liquid stream entering the transfer ladle. The double ladle process was used, with the final pouring temperature sustained near 2550 F.

There is no intent here to show the complete absence of undercooled crystallization of nodular graphite in spherodized iron. However, the degree of undercooling must be relatively minor compared to that of flake graphite in gray iron. This is suggested by the relatively high temperature at which nodules are retained in the rapidly quenched shot. Further evidence of the rapidity of quench is given by the absence of

*Research Metallurgist, Armour Research Foundation of Illinois Institute of Technology, Chicago.

a carbon depleted zone around the nodules and other observations of the microstructure as follows.

In all slow cooled nodular iron, there is ample evidence of carbon depletion in the zone surrounding the nodules. In castings, the nodules are surrounded by a ferritic zone familiarly termed the "bull's-eye" structure. In the large sized shot, the carbide phase appeared to stop short of contact with the graphite by a distance perhaps equal to the interdendritic distance. However, in the very smallest shot, having been very rapidly quenched, the carbide-free zone was very difficult to find.

Part of this difficulty was due to the fineness of the eutectic. The eutectic was so fine as to have a feathery

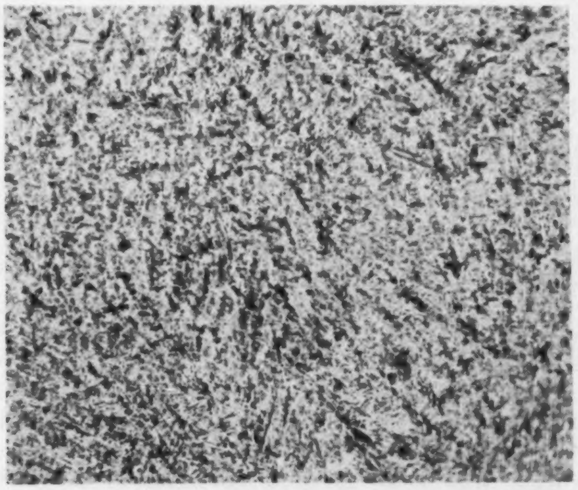

Fig. 1—Graphite precipitate in rapidly quenched gray iron shot. × 500.

structure. Microscopical measurements were made on the interdendritic distance for a number of such very rapidly quenched shot. These distances were on the order of 10^{-5} cm, and the austenic diffusion zone was of the same distance or less.

For comparison, the nodules were of the order of 5×10^{-3} cm diameter. There was no structural variation in the matrix to indicate the occurrence of diffusion during quenching. It was concluded that, at the quenching temperature, the large nodules were essentially in equilibrium with the surrounding liquid, and that the quench was sufficiently rapid so that no appreciable carbide decomposition or carbon diffusion occurred during cooling.

Some perspective on growth of nodules is given from a consideration of graphite growth in solid cast iron. Birchenall and Mead[1] give a review of data on graphite growth rate in cast iron at malleabilizing temperatures. If an average growth rate curve from their Fig. 2 be extended to include growth in the liquid, a schematic arrangement something like that in Fig. 3 might be drawn.

There is no basis to assume that the mechanism of growth at temperatures near the solidus and in the liquid are the same as those occurring at lower temperatures. Nevertheless, Birchenall and Mead's mechanism is reasonable, where carbon diffuses through an austenite zone around the growing graphite nucleus.

[1]Birchenall and Mead; "Growth of Graphite in Cast Iron," *Transactions*, AIME, vol. 8, Aug., 1956, p. 1005.

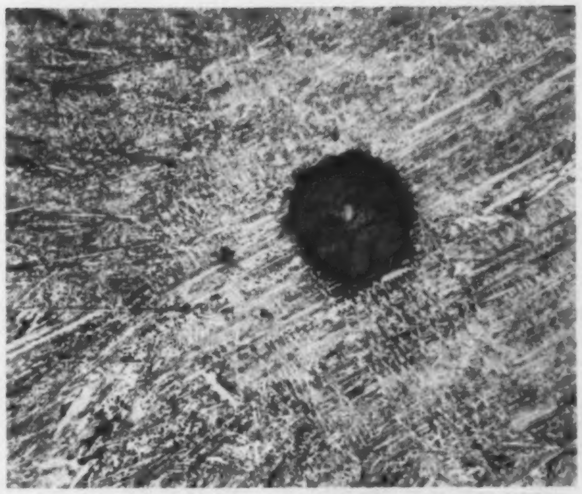

Fig. 2—Nodule in rapidly quenched nodular iron shot. × 500.

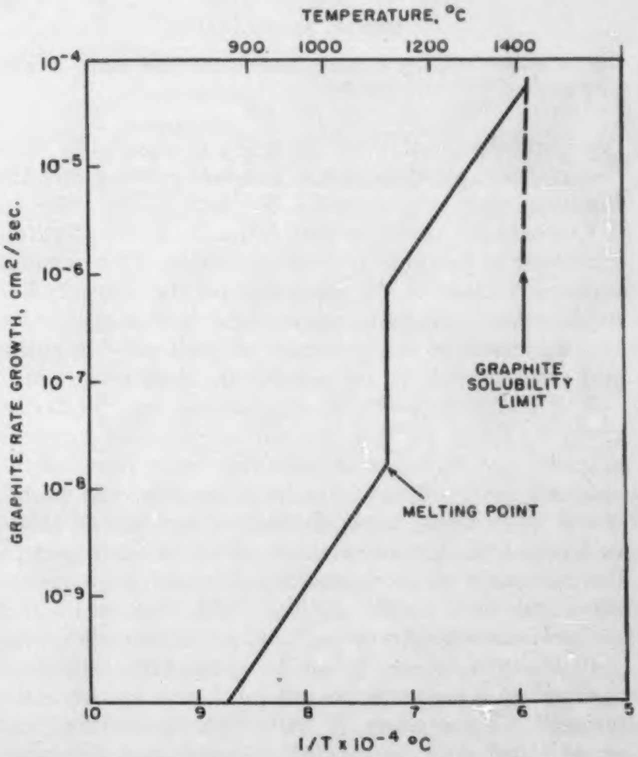

Fig. 3—Schematic graphite growth rate.

Therefore, Fig. 3 shows a linear extrapolation of a mean line through observed growth rates from their figure.

An offset was made to coincide approximately with the isothermal growth time of 3 min at 1400 C. Such an offset would be expected due to the change in state. Upon heating above the liquidus temperature, all the graphite would ultimately dissolve in the melt as indicated by the termination of the growth rate curve in Fig. 3.

The growth rate should not be confused with the nucleation rate which increases rapidly due to the shift of equilibrium upon cooling below the liquidus. This increase in nodule population with lower shotting temperatures was confirmed experimentally. The dearth of nodules in fine shot cast at the higher shotting temperatures is expected due to the increased car-

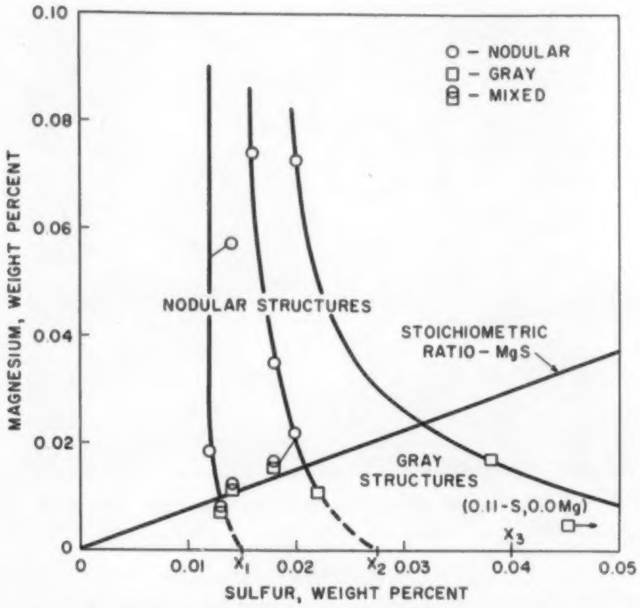

Figure 4—Relationship between magnesium and sulfur in nodular iron.

bon solubility, but their presence confirms the view that nodule growth begins in normal fashion above the liquidus.

Commercial nodular iron is made by appropriate additions to promote nodule formation. This is made eminently clear in the literature on the subject. The explanation most easily understood is that nucleation is suppressed in the presence of melt soluble sulfur and oxygen such as are present in commercial iron.[2]

The mechanism of this suppression may be understood in terms of the low surface tension between graphite and iron containing sulfur, or in terms of the reduced probability of nuclei formation due to the closer association between carbon and sulfur atoms in liquid iron. Either of these effects is destroyed by the formation of stable sulfides. Cerium and magnesium form such stable sulfides, with the result that sulfur is effectively removed, and nodules readily form.

In the surface energy concept, the high interfacial energy between graphite and pure iron has been described[3] as providing a barrier to nucleation and growth and, thus, promoting undercooling. The shotting experiment denies the undercooling effect and requires a different interpretation of the surface energy role. Indeed, it seems more logical that high interfacial tension would promote nuclei growth since it would be more difficult to remove carbon atoms from this stable graphite surface.

The tendency for graphite to redissolve by the reverse reaction would be low, moving the equilibrium toward nodule growth. Sulfur and oxygen in iron more probably tend to increase the solubility of graphite by decreasing the surface tension, and this tendency is exhibited as undercooling.

Now, the mechanism is simple, but is much easier to follow by consideration of Fig. 4. This figure shows the equilibrium obtained in commercial casting operations between magnesium and sulfur with different initial sulfur concentrations. It also shows the necessary ratio between residual magnesium and sulfur required to obtain the nodular structure for various initial sulfur contents.

For example, if the initial sulfur concentration is low, at X1, small magnesium concentrations are required to convert all the sulfur to the sulfide. Further, the sulfur is not removed; the vertical line shows an apparent solubility of 0.012 per cent sulfur or 0.021 per cent magnesium sulfide. With high initial sulfur concentrations, such as at X2 and X3, much sulfur is removed by gravity separation and slag interaction.

For all practical purposes, the chemical reaction between magnesium and sulfur is instantaneous, but the separation of the mixed phases is slow. Therefore, more residual magnesium is required with higher sulfur contents to tie up all the sulfur and assure a nodular structure. There is a zone of uncertainty near the stoichiometric ratio where mixed flake-nodular structures occur due to departures from equilibrium in practice. Otherwise, the graphite structures are given by the areas shown in Fig. 4.

ACKNOWLEDGMENTS

Thanks are due L. L. Clark and W. Rostoker for aid in the experimental program and in preparation of the manuscript. Acknowledgment is made to the Clinton Machine Co. for permission to publish the data.

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[2]Morrogh and Williams; "Graphite Formation in Cast Irons and in Nickel Carbon and Cobalt Carbon Alloys," *Journal of the Iron and Steel Institute*, March 1947.

[3]Keverian, Taylor, and Wulff, "Experiments on Spherulite Formation in Cast Iron," *American Foundryman*, June 1953, p. 85-91.

AMERICAN FOUNDRYMEN'S SOCIETY – PREPRINT NO. 58-15
This paper has been approved for presentation at the 62nd Annual Meeting of the American Foundrymen's Society, to be held in Cleveland, Ohio, May 19-23, 1958. The Society reserves all rights for publication either prior to or subsequent to presentation, and is not responsible for statements or opinions advanced herein.
WRITTEN DISCUSSION IS SOLICITED

CORRELATION OF GREEN STRENGTH, DRY STRENGTH AND MOLD HARDNESS OF MOLDING SANDS

By

R. W. Heine,* E. H. King, and J. S. Schumacher*****

The green and dry compressive strengths of molding sands are usually stated in terms of values obtained from the 2 in. by 2 in. diameter AFS specimen molded by ramming in the standard method. Molds in foundries are made under a wide variety of molding conditions. No standard molding energy is used in foundries to produce molds as is used in molding the standard AFS sand specimen. Thus, the hardness of green sand molds may vary from 40 to 95 mold hardness (Dietert tester) depending on the amount of work done in making the mold.

Not only does the work of molding vary in the foundry, but so do the sand ingredients, particularly the percentage of water in the sand. Therefore to know the properties of sand in a mold, the green and dry compressive strength properties of molding sands need to be measured over a much wider range of molding effort and mold hardnesses than is now done with the standard AFS "three-ram" test. This paper shows how green compressive strength and dry compressive strength of foundry sands at various moisture levels are related to the mold hardness developed by molding.

METHOD OF CORRELATING PROPERTIES

As a starting point consider the iron foundry molding sand described in Table I. This sand, as used in the shop, is basically a southern bentonite bonded sand modified with western bentonite and with seacoal used as an additive for improved finish and cellulose as an additive for flowability. In use, moisture varied between 3.8 and 4.3 per cent or more. Molds made from this sand varied from 60 to 85 mold hardness depending upon the pattern and molding practice.

To prepare 2.0 in. x 2.0 diameter specimens covering this mold hardness range requires the use of special specimen ramming equipment. A rammer equipped with a 2-lb weight as well as the standard 14-lb weight will serve. By varying the number of rams of a 2-lb weight dropped 2 in., specimens of low to high mold hardness and density can be prepared (reference No. 1). Another satisfactory method of specimen ramming involves using a rammer with a 14-lb weight which can be dropped varying heights from 1/4 to 2.0 in. so that the ramming energy applied can be varied to produce low to high compaction and mold hardness levels. Using either ramming method, the weight of sand in the specimen must be regulated so that the number of rams applied may be varied.

TABLE 1 – FOUNDRY SAND A

Sieve Analysis			
U.S. Sieve No.	% Retained		
20	. . .	Bonding Clay	80% S. Bentonite
30	0.4		20% W. Bentonite
40	1.8	Additives	50% D4 Sea Coal
50	13.0		50% Cellulose Material
70	26.8	3 Standard Ram Properties	
100	27.6	H_2O	4.30%
140	15.6	Green Str.	13.7 psi
200	3.0	Dry Str.	123 psi
270	1.0	Ave. Mold	
Pan	0.6	Hardness	86
Total	89.8	Batch Mixture:	
AFS Fineness No.	69.2		3,000 lb used sand
% AFS Clay	10.2		5 lb sea coal
% Total			5 lb cellulose
Combustible	4.92		8 lb bonding clay

Typical data obtained in this way are shown in Table 2 for this sand at 4.30 and 3.80 per cent moisture. This data may then be plotted as a graph relating green and dry strength to *average mold hardness*† for the sand at 4.3 and 3.8 per cent water as in Fig. 1. Figure 1 shows that green strength of this sand at a particular mold hardness is essentially the same at both 3.8 and 4.3 per cent moisture in the sand. It should be emphasized that different amounts of ramming energy are necessary to develop the same mold hardness for different moisture levels, yet at the same mold hardness the green strength is essentially the same (reference No. 1).

While the green strength of a particular sand is

* Associate Professor of Metallurgical Engineering, Department of Mining and Metallurgy, University of Wisconsin; Madison, Wisc.
** Vice-President, The Hill and Griffith Co., Cincinnati, Ohio.
***Chief Engineer, The Hill and Griffith Co., Cincinnati, Ohio.

†Average mold hardness refers to the average of six readings, three taken on the bottom and three taken on the top of the 2.0 in. x 2.0-in. diameter specimen.

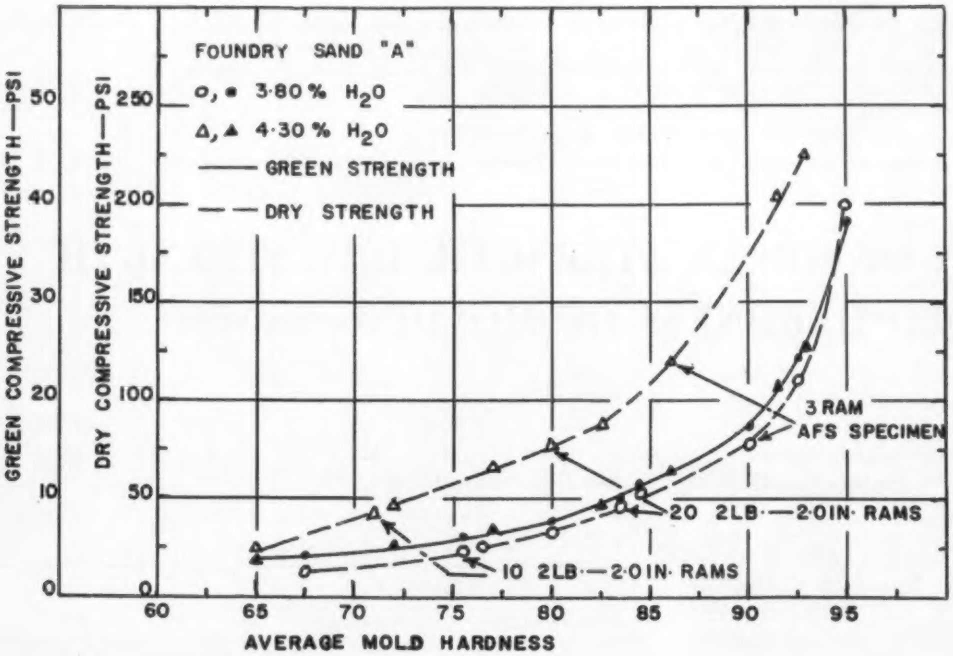

Fig. 1 – Graph of average mold hardness versus green and dry compressive strength of foundry sand A at 3.8 and 4.3% H_2O.

the same at a given mold hardness in spite of moisture variation, dry strength at the same green mold hardness is much higher in higher moisture content sand. Figure 1 shows that both dry strength and green strength increase but slowly with increasing mold hardness until a hardness in excess of 80 to 85 is reached. At a low mold hardness of 65, a very low green strength and dry strength exist which are not revealed by the properties obtained from the standard 3-ram AFS specimen. The standard 3-ram properties are noted on Fig. 1, as are also properties for 10 and 20 2-lb 2.0-in. rams.

The latter are important points because they correspond to the mold hardness and molding energy of 10 and 20 jolts of 3.0-in. stroke as commonly found on better molding machines.* Properties of the sand at the parting line are most commonly determined by the jolting operation. Thus the 10- and 20-ram properties are those likely to be developed at the parting by 10 or 20 jolts. Comparison with the standard 3-ram properties shows the inadequacy of basing sand control on the standard test only.

TABLE 2

Mold Hardness No.	Compressive Strength, Psi Green	Dry	Specimen Wt., grams	No. of Rams
	Properties of Foundry Sand A at 4.3% H_2O			
64	3.6	24	130	5– 2-lb Rams
72	5.5	47	135	11– 2-lb Rams
77	7.1	66	140	15– 2-lb Rams
82.5	9.7	82.5	145	25– 2-lb Rams
86	13.7	123	155	3–14-lb Rams
91.5	21.7	203	160	6–14-lb Rams
93	25.3	225	165	8–12-lb Rams
	Properties of Foundry Sand A at 3.8% H_2O			
67.5	4.0	13	130	5– 2-lb Rams
75.5	6.1	24	135	10– 2-lb Rams
80	7.9	35	140	13– 2-lb Rams
83.5	10.0	47.0	143	20– 2-lb Rams
90	17.0	77	155	3–14-lb Rams
92.5	24.0	110	160	5–14-lb Rams
95.0	38.0	190	165	10–14-lb Rams

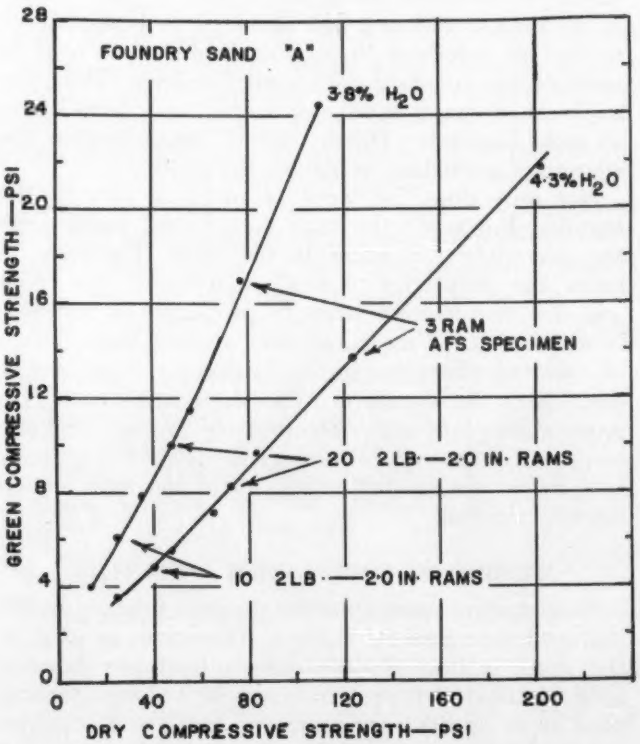

Fig. 2 – Graph of green compressive strength versus dry compressive strength of foundry sand A at 3.8 and 4.3% H_2O.

The data in Fig. 1 may be replotted as a relationship of dry strength to green strength, as in Fig. 2. Thus in Fig. 2 it is shown that dry strength of a given sand is dependent on moisture content and the green strength (or mold hardness) to which the sand is rammed. Although only 3 levels of ramming energy are shown in Fig. 2, it is evident that the relationship holds over a wide range of ramming from the minimum to maximum. So, to understand sand behavior in the mold, the properties of the sand must

*See p. 401, vol. 64, AFS TRANSACTIONS relating to jolt stroke and table loadings on jolt machines.

be determined over a wide range of molding energy or mold hardness.

Also, the change of these properties over the range of moldable moisture contents must be determined. The moisture effect fixes a particular curve on the green strength-dry strength graph of Fig. 2. Figure 3 shows how the green strength-dry strength relationship varies in this foundry sand over the moisture range of 3.3 to 4.9 per cent. This moisture variation for this sand covers the range of sand too dry for molding to over-wet for molding. The points on each curve in Fig. 3 corresponding to the standard 3-ram properties, and 20 and 10 2-lb 2.0-in. rams are connected so that the properties existing at each ramming level are evident.

Numbers alongside the curves in Fig. 3 refer to average mold hardness at that point. In the usual sand control practice, only the combinations of green strength, dry strength, and moisture content shown on the 3-ram curve in Fig. 3 are reported. While the standard 3-ram properties may be adequate yet the properties at the lower mold hardness levels which usually exist in the mold may be quite inadequate.

The green strength-dry strength relationship in Figure 3 is greatly influenced by moisture content. However, the green strength-mold hardness relationship is not significantly altered by moisture content within the moldable range as shown in Figure 4 for the range of 3.3 to 4.9 per cent moisture in foundry sand A. Thus, in order to obtain the complete relationship of green strength and dry strength between the sand in 2.0 in. x 2.0 in. D specimens and the sand in a mold, it is necessary to know moisture content of the sand as well as average mold hardness.

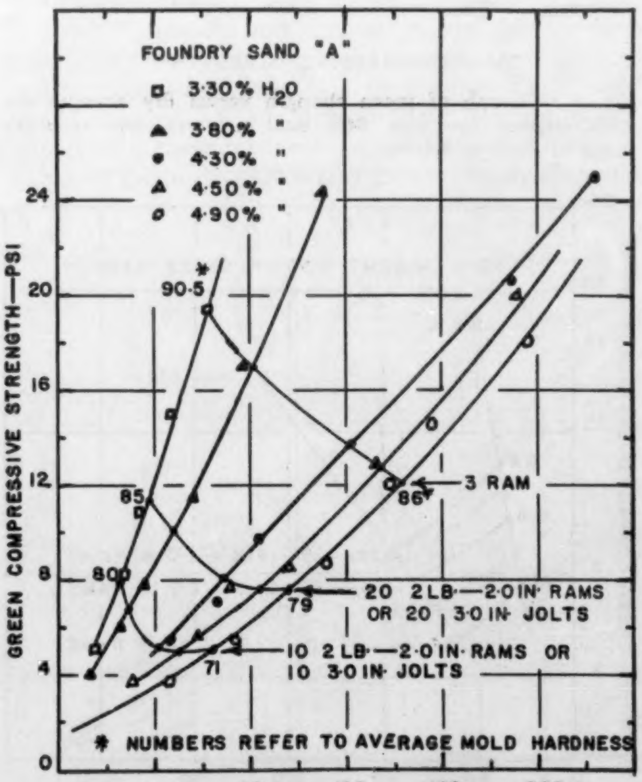

Fig. 3 – Graph of green compressive strength versus dry compressive strength of foundry sand A at five different moisture contents.

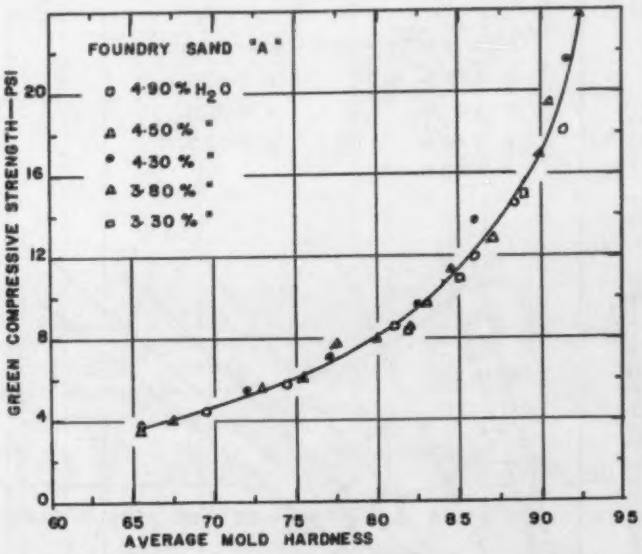

Fig. 4 – Graph of average mold hardness versus green compressive strength for foundry sand A at five different moisture contents.

The mold hardness achieved in a particular sand mixture is determined by the ramming effort applied and the moisture content of the sand. A higher moisture content causes a lower mold hardness (and green strength) to be developed from fixed molding energy. For example in Fig. 1, the 3-ram properties of foundry sand A are 90 average mold hardness (17.5 psi green strength) at 3.8 per cent H_2O and 86 average mold hardness (13.5 psi green strength) at 4.30 per cent H_2O. Corresponding dry compressive strengths are 77 psi at the lower moisture and 123 psi at the higher moisture content.

Similar changes in properties occur when specimens are rammed to lower mold hardness. Thus two graphs of the kind shown in Figs. 3 and 4 can be used to fully describe the relationships of green strength, mold hardness, dry strength, moisture content and amount of work done in molding. The mold hardness and moisture tests then become means of relating properties of the sand specimen to properties in the mold.

Consider another example of the use of Figs. 3 and 4. In a mold, mold hardness at one point is found to be 75. From Fig. 4, a green strength of 6.0 psi corresponds to a mold hardness of 75. Referring to Fig. 3 at 6.0 psi green strength, dry compressive strength may vary from 18.0 to 80.0 psi depending on the percentage of moisture in the sand. If the moisture is known as 4.30 per cent, then dry compressive strength is fixed at 50 psi at 6.0 psi green strength.

At this point, the correlations discussed in the preceding paragraphs apply only to the specific foundry sand tested (foundry sand *A*). A more general approach showing how these relationships are affected by various clay types and percentages may now be considered.

EFFECT OF CLAY TYPE AND AMOUNT

Using the techniques described, new sand mixtures were made with an 85 AFS, 4-screen sand and western

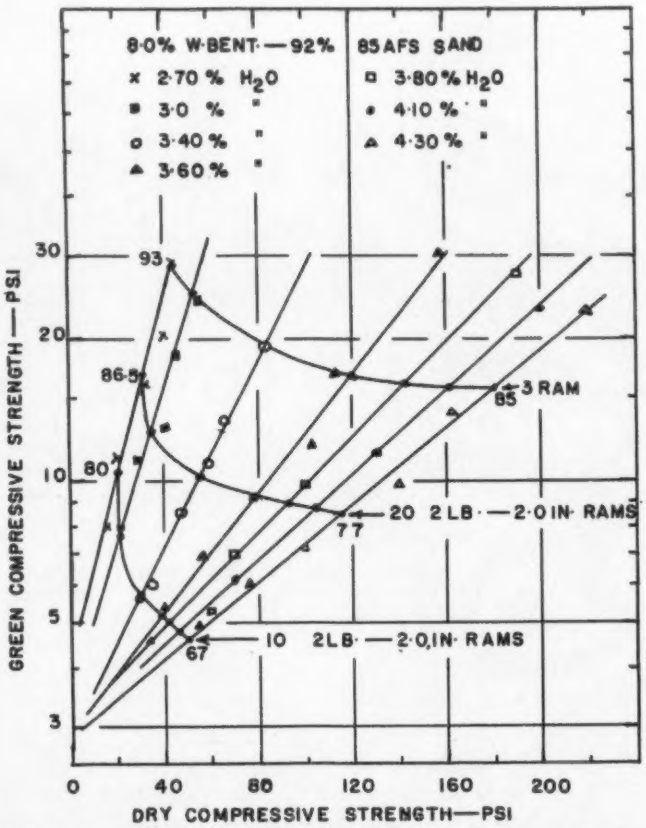

Fig. 5 – Graph of green strength versus dry strength for 8.0% western bentonite 92% sand mixture at seven moisture contents.

At 6.10 psi green compressive strength in the 6 per cent western bentonite of Fig. 6, dry strength increased from 19.0 psi to 80.0 psi as moisture content increases from 2.20 to 3.40 per cent. In Fig. 5 for the 8.0 per cent western bentonite mixture, dry strength at 7.5 psi, green strength increases from 13.0 to 102 psi as moisture content increases from 2.7 to 4.03 per cent. All the aforementioned properties occur at the 75 mold hardness initially selected for the example. This illustrates the fallacy of considering mold hard-

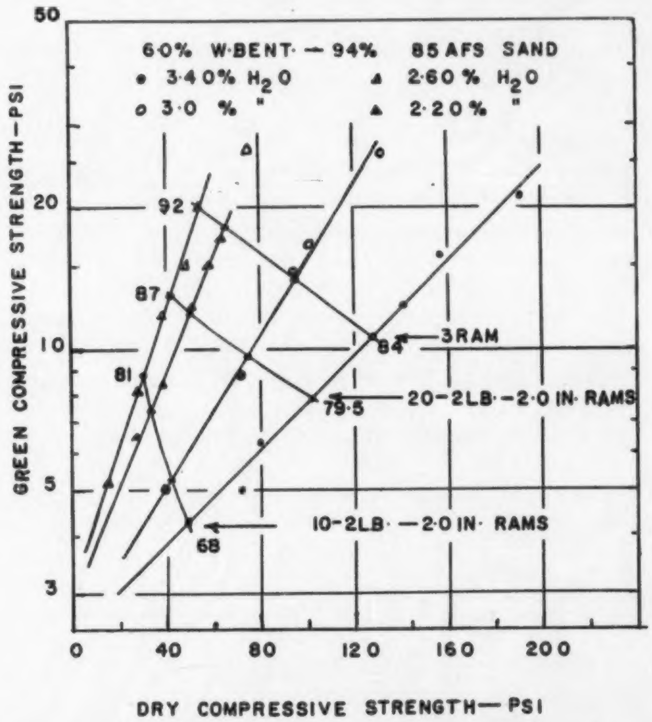

Fig. 6 – Graph of green strength versus dry strength for 6.0% western bentonite 94% sand mixtures over moisture range of 2.20 to 3.40%.

bentonite, with a range of clay and moisture contents. Mold hardness, green strength, and dry strength were determined as reported earlier. Similar new sand mixtures were made with 55 AFS and 65 AFS 4-screen silica sands as the base sand. Only the results obtained with the mixtures containing the 85 AFS sand will be considered here as the other mixtures produced substantially the same or identical results.

Western Bentonite

Mixtures of 3, 6, and 8 per cent western bentonite were studied over the moisture range of too dry to over-wet for molding. The relationship of dry strength to green strength at various moisture levels is shown in Fig. 5 for the 8 per cent western bentonite mixture. Figures 6 and 7 show the same relationships for 6 per cent and 3 per cent western bentonite mixtures, respectively. The relation of green strength to average mold hardness is shown in Fig. 8 for each clay content and all the moisture levels presented in Figs. 5, 6, and 7. Figures 5, 6, 7, and 8 are plotted on the semilogarithmic scale in order to cover a wider range of green strength values. Again numbers alongside the curves in Figs. 5, 6, and 7 refer to average mold hardness at that point.

Consider an example of the use of these graphs. At a 75 mold hardenss, green strength from Fig. 8 would be 4.75, 6.10, and 7.5 psi in 3, 6 and 8 per cent western bentonite mixtures, respectively. Referring to Fig. 7 at 4.75 psi green strength, dry compressive strength of the 3 per cent western bentonite mixtures would increase from 22 to 67 psi as moisture increases from 2.0 to 3.20 per cent.

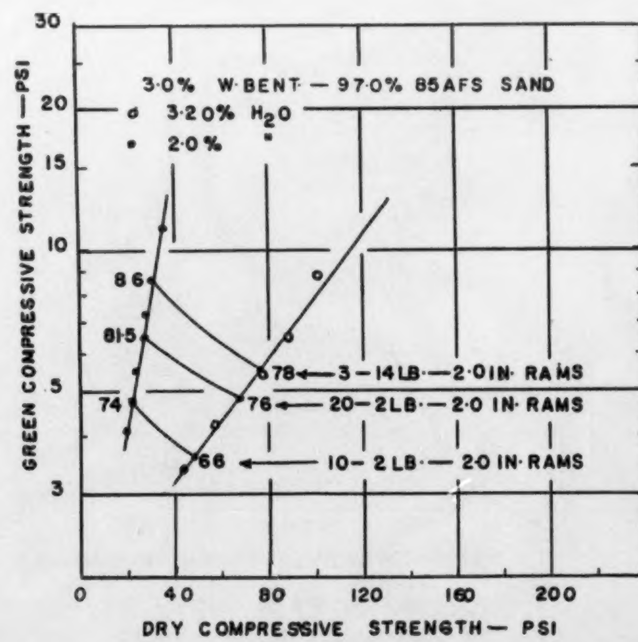

Fig. 7 – Graph of green strength versus dry strength for 3% western bentonite 97% sand mixtures over range of 2-3.20% moisture.

ness alone when referring to properties of the sand in the mold.

Moisture and clay percentages must also be stated in order to describe the green and dry compressive strength of the sand in a mold at any mold hardness. However, the lower limit of these properties appears to be the same at any moisture and clay content as mold hardness decreases toward 60 (equivalent to about 3.0 psi green strength). As the 2.0 in. x 2.0 in. diameter specimen is molded to higher hardness and density, differences in dry strength due to moisture and clay content are increased.

Southern Bentonite

Southern bentonite bonded sands were also studied by the same method. New sand mixtures of 3, 6, and 8 per cent southern bentonite balance 85 AFS 4-screen sand and varying moisture content were tested and the same types of graphs prepared, with results shown in Figs. 9, 10, 11, and 12. These graphs are used in the same manner as illustrated in the case of foundry sand A and the western bentonite mixtures.

Again, as mold hardness decreases toward 60 (equivalent to about 3.0 psi green strength), the green and dry properties at all clay and moisture contents fall in the same low range and the effect of moisture content predominates on dry strength. Differences in dry strength due to moisture content and clay content are increased as the 2.0 in x 2.0 in. diameter specimen is molded to higher mold hardness and density.

Fire Clay

Fire clay bonded sands were studied by the same method. New sand mixtures of 10 and 15 per cent fire clay, balance 85 AFS 4-screen sand, and varying moisture contents from 4.0 to 6.4 per cent were tested. Figures 13, 14, and 15 show the results obtained with these mixtures. Again, the same range of values of green strength and dry strength are obtained as in the case of western and southern bentonite

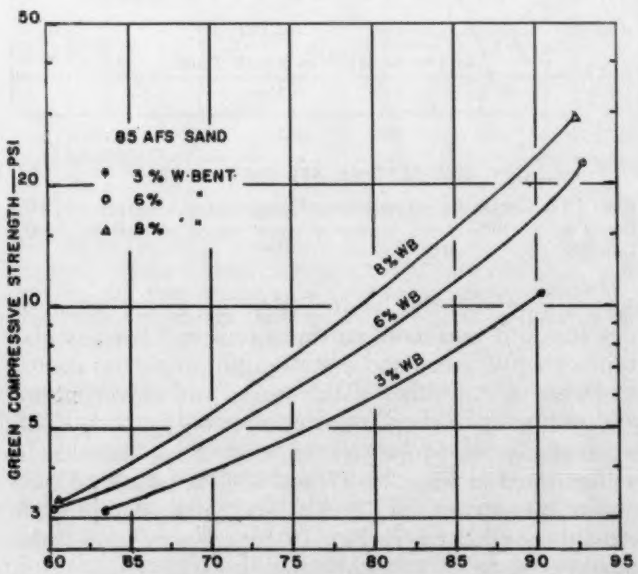

Fig. 8 – Graph of average mold hardness versus green strength for three western bentonite sand mixtures.

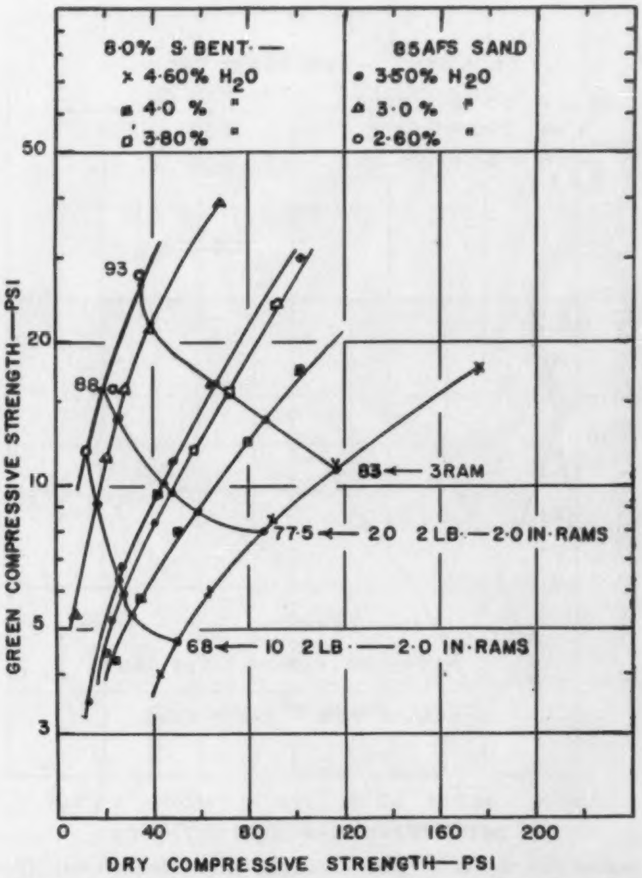

Fig. 9 – Graph of green strength versus dry strength for 8.0% southern bentonite – 92% sand mixture over range of 2.6-4.60% moisture.

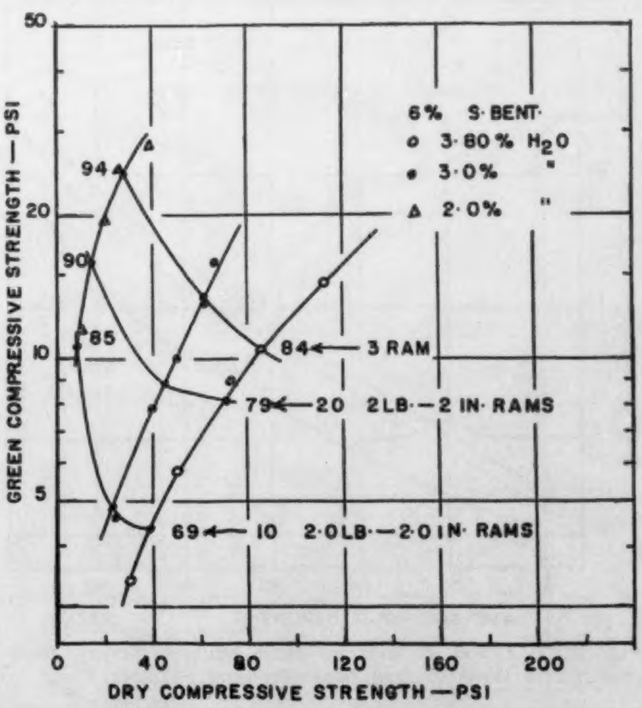

Fig. 10 – Graph of green strength versus dry strength for 6.0% southern bentonite – 94% sand mixture over range of 2.0-3.8% moisture.

bonded sands, although the clay and moisture content required are higher.

As in the case of the bentonite bonded sands, the mold hardness level developed by molding has a

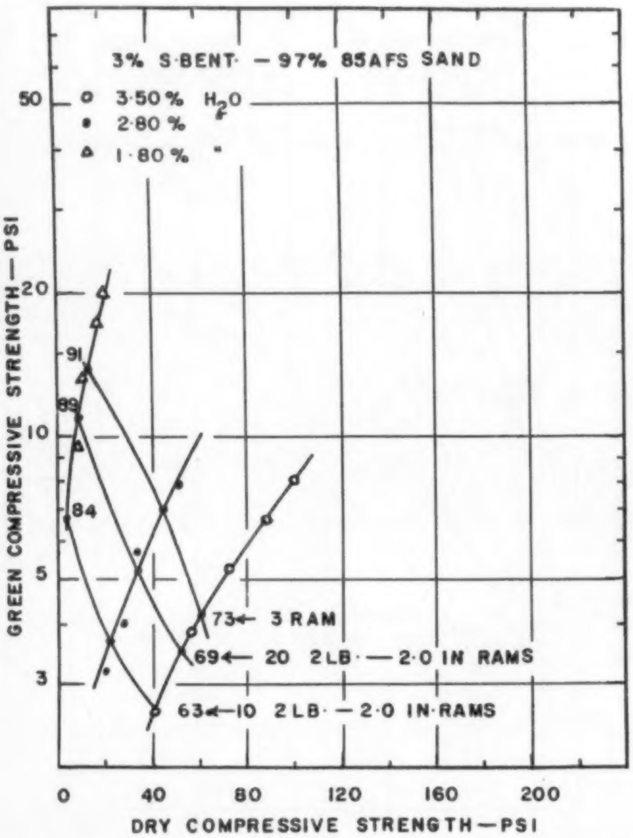

Fig. 11 – Graph of green strength versus dry strength for 3.0% southern bentonite – 97% sand mixtures over range of 1.8-3.50% moisture.

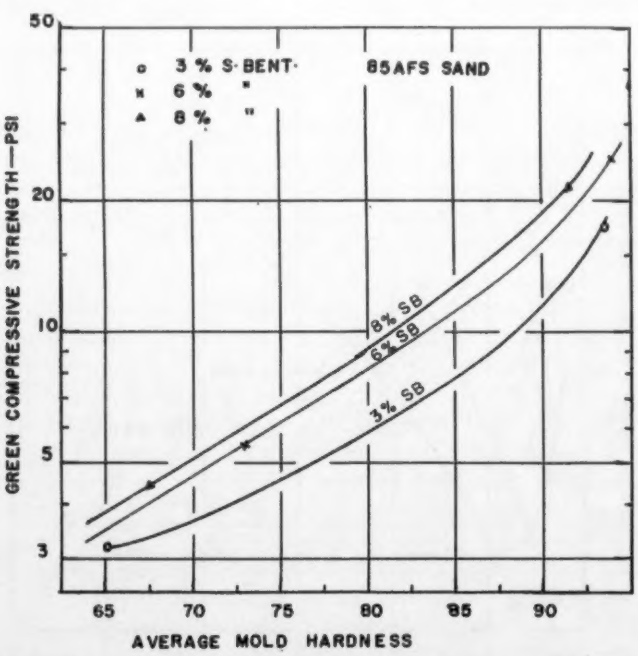

Fig. 12 – Graph of average mold hardness versus green strength for three western bentonite sand mixtures.

major effect on the actual properties developed. Further, as mold hardness decreases toward 60 (equivalent to 3.0 psi green strength) dry strength falls into the same low range as with the bentonite sands with moisture content having a dominating effect.

Equivalence of Clay Types

The experimental work shows that all the mixtures

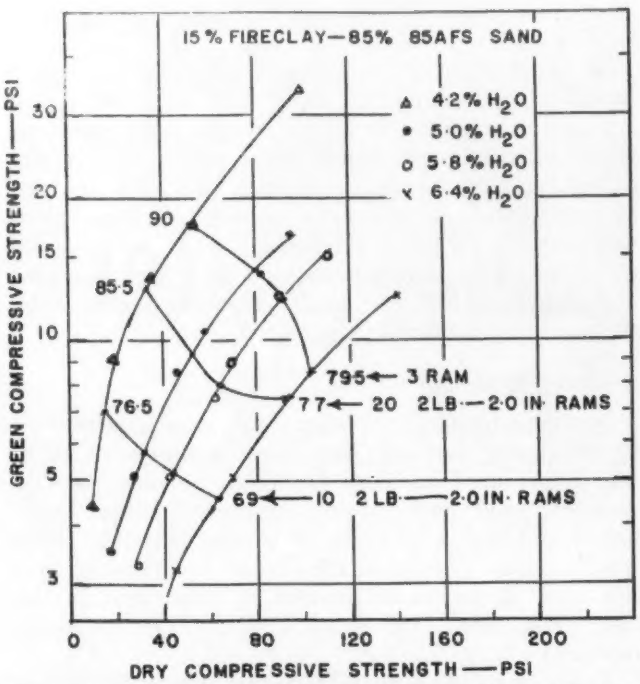

Fig. 13 – Graph of green strength versus dry strength for 15% fire clay 85% sand mixtures at 4.2 to 6.4% moisture.

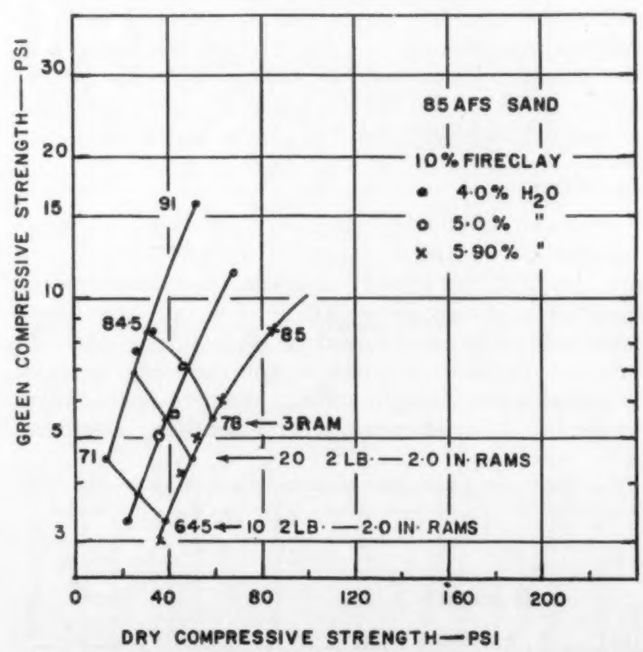

Fig. 14 – Graph of green strength versus dry strength for 10% fire clay – 90% sand mixtures over range of 4.0 to 5.90% moisture.

tested produce the same range of green strength, dry strength, and mold hardness results. Thus any clay type can give green and dry strength properties similar to those of any other if the water and clay contents and ramming of the sand are adjusted properly. This equivalence of properties as related to ramming is summarized in Figs. 16, 17 and 18. The standard AFS 3-ram properties of green and dry compressive strength are shown in Fig. 16 for all clay-sand-water mixtures tested.

The green strength-dry strength curves shown in Fig. 16 are simply the corresponding curves of 3-ram properties taken from Figs. 5, 6, and 7 for the western

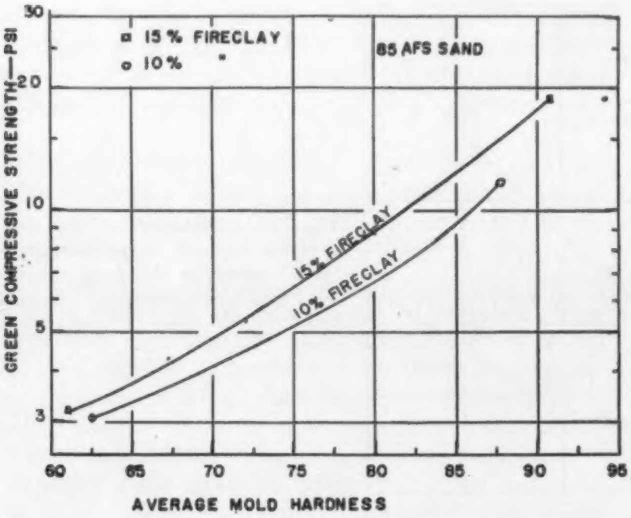

Fig. 15 – Graph of average mold hardness versus green strength for two fire clay-sand mixtures.

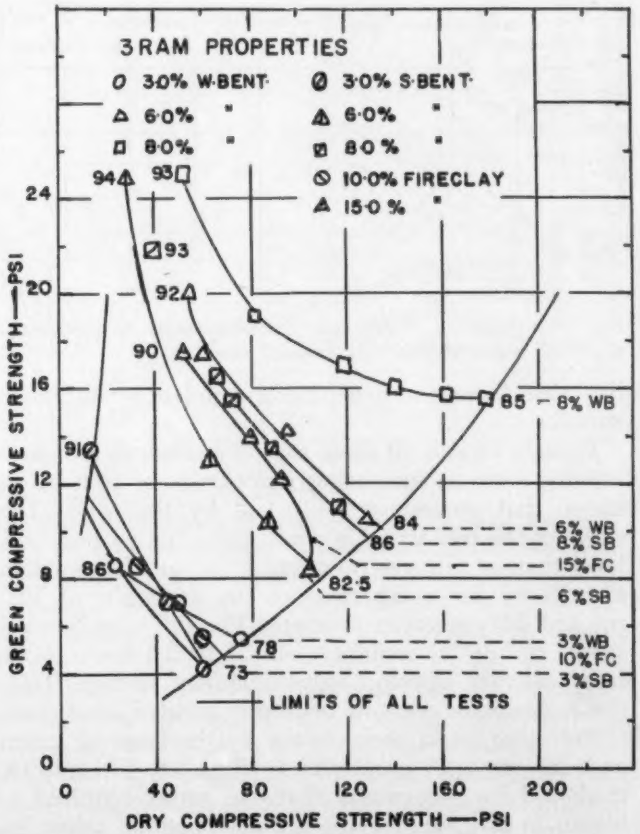

Fig. 16 – Graph of combinations of green strength and dry strength obtained from the standard 3-ram AFS test with varying clay content and type. One curve represents one clay type and pencentage having an increasing percentage of moisture from left to right.

bentonite mixtures; Figs. 9, 10, and 11 for the southern bentonite mixtures; and Figs. 13 and 14 for the fire-clay mixtures. They are collected on Fig. 16 so that they may be compared. From Fig. 16, it appears that 6-8 per cent western bentonite, 6-8 per cent southern bentonite, and 15 per cent fire clay produce standard 3-ram property combinations of green and dry strength that are roughly comparable.

Specifically, 6.0 per cent western bentonite, 8 per cent southern bentonite, and 15 per cent fire clay

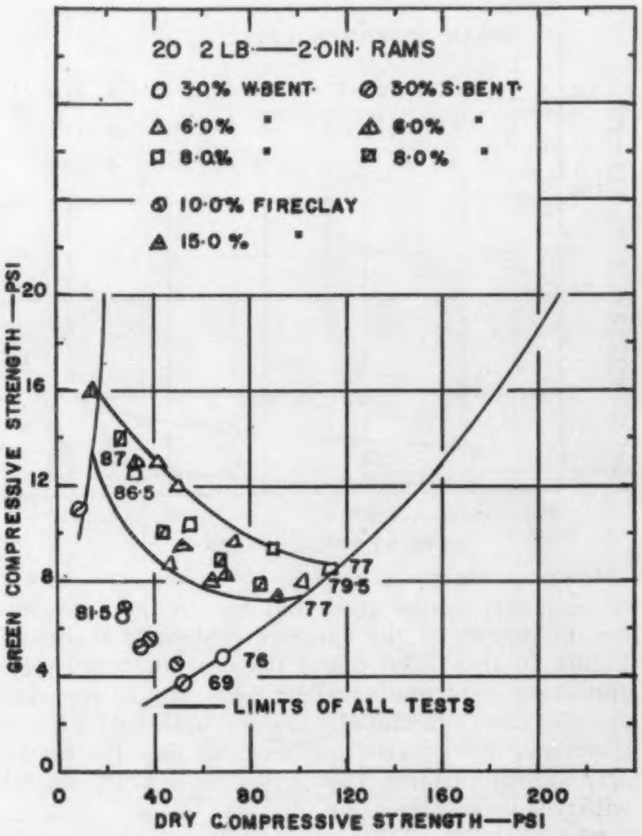

Fig. 17 – Same as Fig. 16, but for 20 rams of a 2-lb weight dropped 2.0 in.

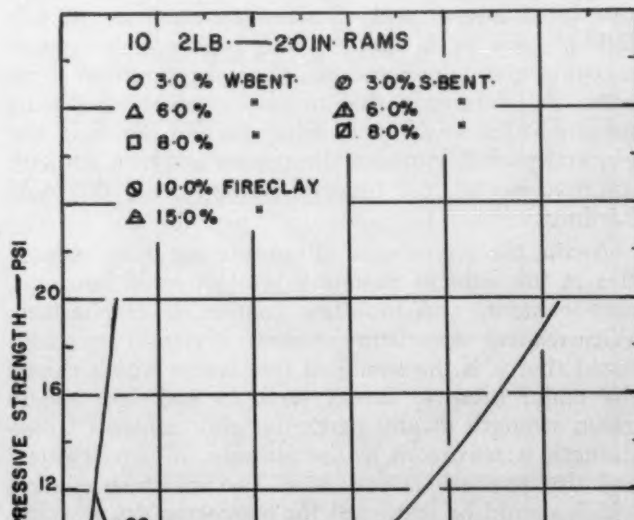

Fig. 18 – Same as Fig. 17, but for 10 rams of a 2-lb weight dropped 2.0 in.

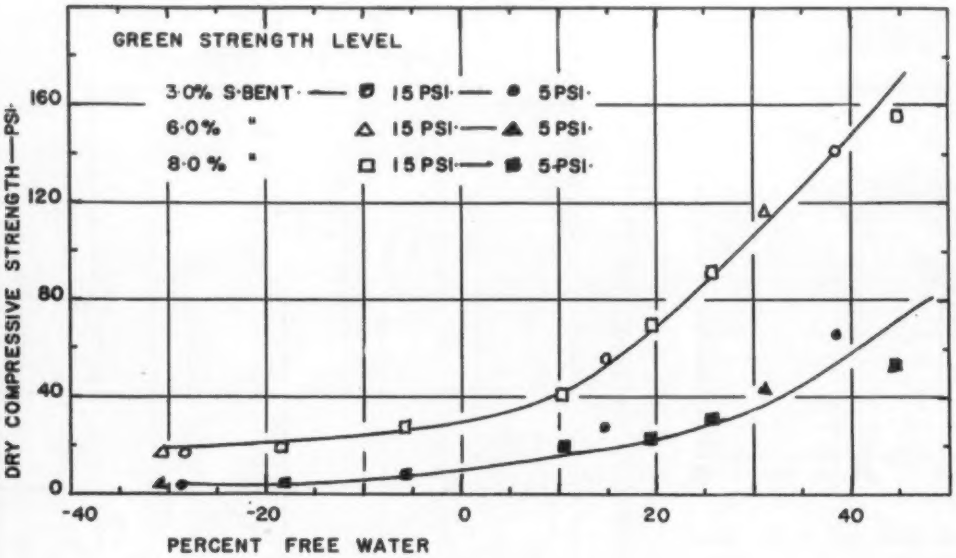

Fig. 19 – Relation of dry compressive strength to percentage of "free" water in the sand mixture for southern bentonite bonded sand.

develop very similar green and dry strengths depending, of course, on the moisture content of the sand. Figure 16 also shows that 3 per cent western bentonite, 3 per cent southern bentonite, and 10 per cent fire clay show substantially lower standard AFS 3-ram green and dry strength combinations than the higher clay content mixtures. This is very much in agreement with past knowledge.

The generalizations just stated for the standard 3-ram properties also apply at a lower level of ramming such as 20 2-lb 2.0-in. rams as shown in Fig. 17. The higher clay content mixtures show a higher level of green strength-dry strength combinations. Likewise, at a still lower level of ramming such as 10 2-lb 2.0-in. rams as in Fig. 18 the higher clay content mixtures give higher combinations of properties. However, the difference due to clay content diminishes greatly at the lower mold hardness and ramming levels, and probably almost disappears as green strength approaches 3.0 psi (equivalent to about 60 mold hardness).

Again, the importance of considering these properties in the light of ramming level or mold hardness, clay content, and moisture content is emphasized. With respect to moisture content, it should be recognized that it is the so-called free water which causes the major increase in dry strength and decrease in green strength at any particular clay content. Green strength is maximum in the absence of "free" water[2] and dry strength is very low. The moisture content which should be exceeded for increasing dry strength may be calculated by the method described in reference 3.

The water percentage absorbed is calculated by this method[3] and then additional water added for dry strength. For example, if a 3.0 per cent water is calculated as that absorbed, then an additional 10 to 30 per cent of the calculated value might be added to obtain dry strength and 3.30 or 3.90 per cent would be used. The effect of the percentage of free water above the calculated absorbed percentage is shown in Fig. 19 for southern bentonite sands and Fig. 20 for fire clay sands. Western bentonite bonded sands have absorbed and free water behavior

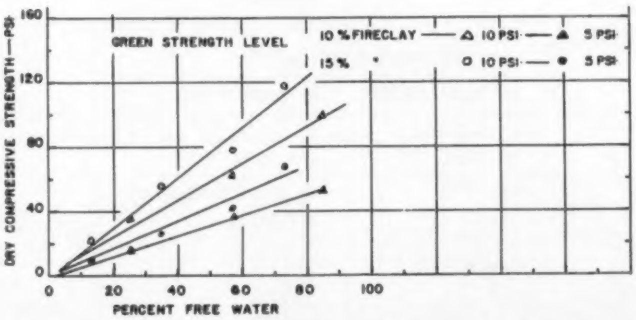

Fig. 20 – Relation of dry compressive strength to percentage of "free" water in fire clay bonded sand.

like that of southern bentonite bonded sands, reference 3.

Figures 19 and 20 show that dry strength increases rapidly with an increasing percentage of free water above that percentage absorbed by the sand. The effect of the free water is greater at a higher ramming level than at a lower ramming level, as illustrated in Fig. 19 by the comparison of dry strengths of 15.0 psi and 5.0 psi green strength. The fire clay bonded sands in Fig. 20 require about 2 to 2.5 times more free water to develop equivalent dry strength than the southern or western bentonite bonded sand does.

Referring back, then, to the comparisons of green and dry strength properties in Figs. 16, 17, and 18, it should be recognized that the water required is higher in all cases for the fire clay bonded sands. In addition, it should be recognized that clays of different types and different geological deposits of the same clay type have different requirements of water within the general concept of free and absorbed water. These differences have been pointed out in the absorbed moisture calculation method described in reference 3 of the bibliography.

To summarize the equivalence of clays in producing combinations of green and dry compressive strength, and mold hardness, Figs. 21, 22, and 23 are presented. The relationship of average mold hardness to green strength is shown in Fig. 21 for the three clay types. The range of green strength-dry strength combinations expected from the higher clay percentages is shown in Fig. 22 for three different levels of

ramming. The same range is shown for the lower clay contents in Fig. 23. Clay contents intermediate between the percentages reported fall at intermediate positions on the graphs of Figs. 21-23.

General Application

The principles delineated apply to a wide range of foundry sands. The initial test work describes results obtained with iron foundry sand A, Figs. 1-4. The subsequent data, Figs. 5-23, summarizes results obtained with new sand mixtures. To correlate these results with used foundry sands, the authors obtained data on a number of sands used for green sand molding in foundries. These foundry sands were tested as used in the foundry and at various moisture contents and ramming levels.

Foundry sand practice using the three types of clay were included. The combinations of green strength and dry strength obtained from these foundry sands are shown in Fig. 24. The results fall within the

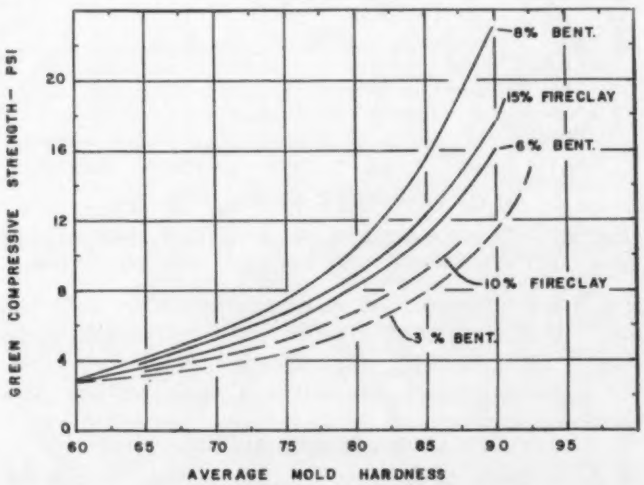

Fig. 21 — Relationship of green strength to mold hardness of 2.0 in. x 2.0 in. diameter test specimen for all clay-sand mixtures tested.

same range of values obtained in all mixtures tested earlier.

However, it should be expected that dry strength values to the right of the curves in Fig. 24 will occur in foundry sands used for dry sand molding. This has in fact been found to be the case. Green sands for the dry sand molding practice use in general a higher percentage of moisture than that included in the limits set-up on all the preceeding figures.

Recognizing this, it is now possible to set-up the combinations of sand properties, moisture content, molding level and clay content range as expected in green and dry sand molding practice. This is done in Fig. 25. Thus, practically all molding sands can be expected to show combinations of green and dry compressive strength falling in the ranges shown in Figs. 1-24 and summarized in Fig. 25. The mold hardness value in combination with a hardness-green strength curve such as Fig. 21 and the moisture content of the sand serves to spot the location of the green strength-dry strength combination on the summary graph.

Finally, it should be stated that all the data for new

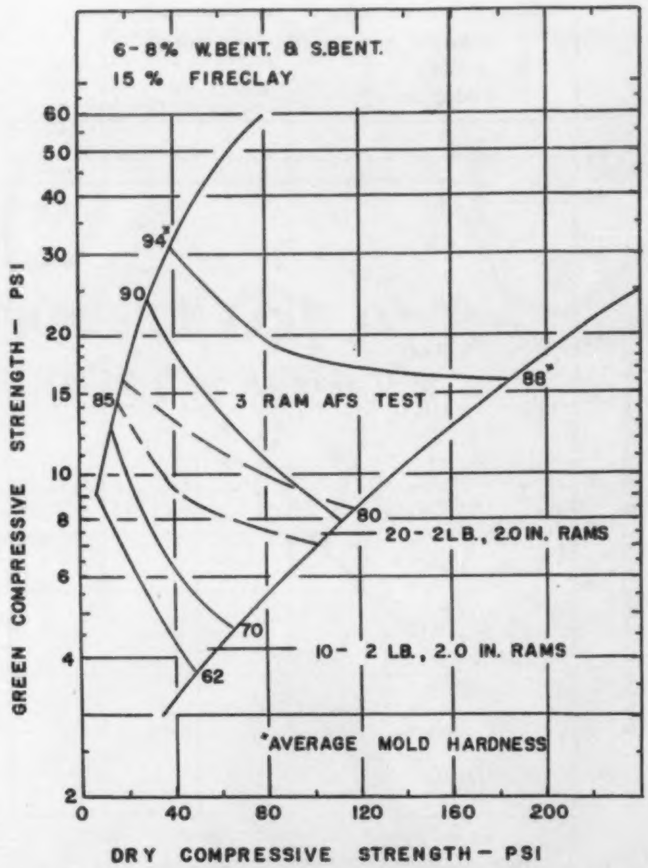

Fig. 22 — Combinations of green strength and dry strength expected in clay-sand mixtures containing 6 to 8% bentonite or 15% fire clay at different levels of ramming.

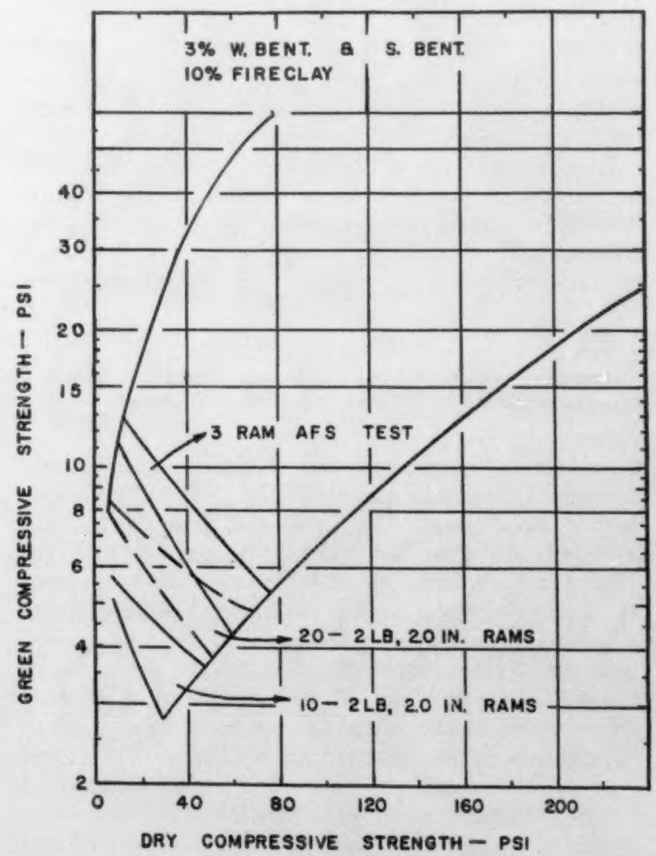

Fig. 23 — Same as Fig. 22, but for 3% bentonite or 10% fire clay.

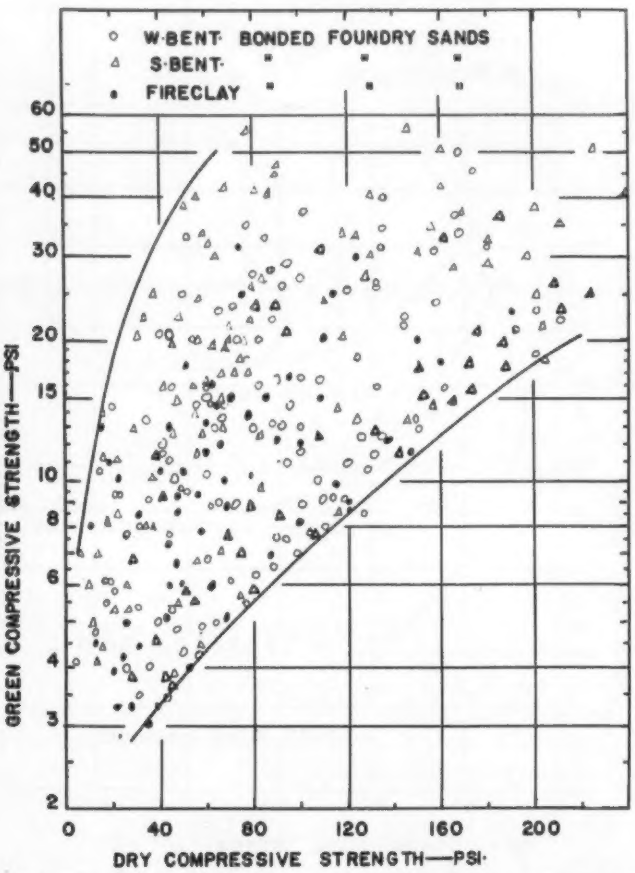

Fig. 24 – Combinations of green strength and dry strength found in foundry sands.

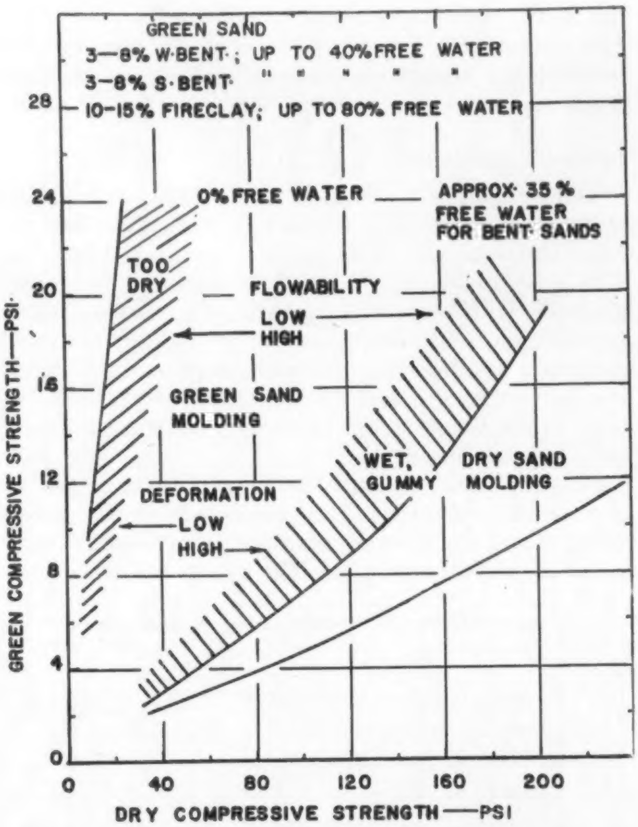

Fig. 25 – Schematic diagram showing the relationships of green and dry strength with flowability and deformation.

sand mixtures was obtained from sands that were fully mulled. Foundry sands show the same relationships if they are fully mulled. Under-mulled sands usually show low dry strength at a given green strength and moisture content. Therefore, the importance of mulling in duplicating these results is emphasized.

In addition, it should be recognized that small shifts in the location of the curves for average mold hardness, green and dry compressive strength, moisture content, and ramming level will be caused by changes in clay quality, sand type and sieve analysis, additives, mulling technique, ion exchange behavior, etc., i.e., the variables of sand practice. But, the general technique of correlating the aforementioned properties of a molding sand remains as a basic tool of sand control.

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AMERICAN FOUNDRYMEN'S SOCIETY – PREPRINT NO. 58-14
This paper has been approved for presentation at the 62nd Annual Meeting of the American Foundrymen's Society, to be held in Cleveland, Ohio, May 19-23, 1958. The Society reserves all rights for publication either prior to or subsequent to presentation, and is not responsible for statements or opinions advanced herein.
WRITTEN DISCUSSION IS SOLICITED

DEOXIDATION PRACTICE FOR COPPER SHELL-MOLDED CASTINGS

By

R. C. Harris*

ABSTRACT

It has been found that serious impairment of tensile properties can occur in pure copper castings made by the shell-molding process. Because of the nature of the decomposition products of the phenolic resin used in connection with this process, it appears that embrittlement of the castings occurs as a result of the familiar "steam reaction." The reducing gases, generated when the heat of the cast metal decomposes the resin, react with oxides within the melt to form steam, which then causes rupturing at grain boundaries. Four deoxidizers, namely, titanium, lithium, phosphorus and calmium boride were investigated as a means of preventing the embrittlement. Of these, only titanium and lithium were found to be effective. Three types of melting equipment were utilized: gas-fired; 3,000 cycles per second (cps) induction equipment; and 20,000 cps induction equipment. Gas-fired and the 20,000 cps equipment were found to be suitable for melting pure copper.

INTRODUCTION

In the pouring of pure copper castings, proper deoxidation is essential in order to maintain adequate physical and mechanical properties. Studies conducted at Pitman-Dunn Laboratories, Frankford Arsenal, have indicated that deoxidation is even more critical for shell-molded copper castings than for castings produced by other methods, such as sand casting. Copper shell-molded castings recently poured were found to be embrittled by a network of intergranular cracks throughout the castings. Figure 1 is a photograph of one of these castings examined by means of the fluorescent-penetrant process for crack detection.

One of the recognized and most familiar mechanisms producing embrittlement in copper is the reaction between hydrogen and copper oxide to form steam, commonly called the "steam reaction." Embrittlement occurring from a reaction of this type is dependent on a hydrogen source. Since standard deoxidation practice was not effective in the shell mold, it would appear that a high concentration of hydrogen exists in the mold gases generated within this type of mold.

In a green-sand, mold, for example, the principal

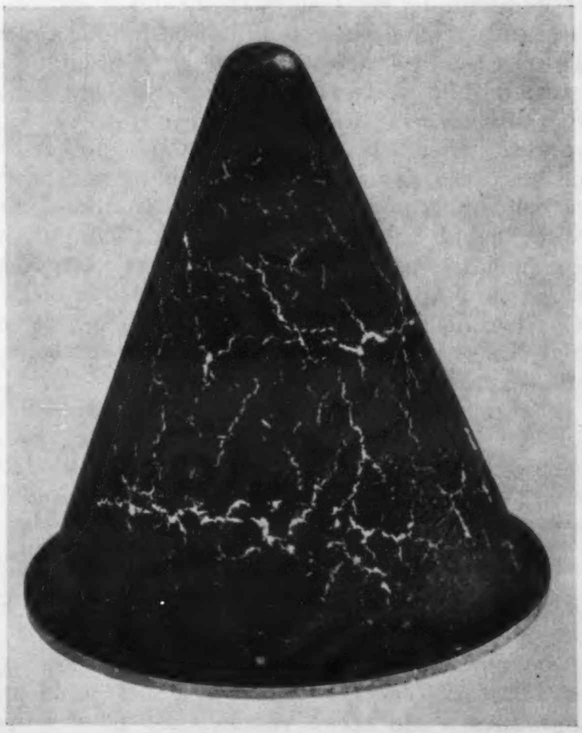

Fig. 1 — Embrittled casting treated by fluorescent-penetrant process for crack detection (ultra-violet illumination).

source of hydrogen is the dissociation of the water vapor within the mold. Even at the casting temperature of copper, however, this dissociation is very small. The large percentage of resin in the shell-mold material generates large volumes of gaseous decomposition products when heated, which are known to be highly reducing in nature. Presumably, these gases are rich in hydrogen. It is therefore reasonable to expect that the mold gases in the shell mold would produce a more severe environment for embrittlement of copper than would be the case in the sand mold.

A substantial amount of work has been reported in the literature on the subject of hydrogen embrittlement of copper. Rhines and Anderson[1] studied embrittlement of copper specimens heated in a hydro-

*Metallurgist, Pitman-Dunn Laboratories, Frankford Arsenal, Philadelphia, Pa.

gen atmosphere for various times and temperatures. It was demonstrated by these investigators, and also by Wyman,[2] that the diffusion of hydrogen in solid copper is quite rapid, and particularly so at temperatures above approximately 700 C.

Hydrogen diffusing into the copper reacts with the copper oxide to form steam. The resulting steam produces sufficient pressure to rupture the grain boundary.[3]

It has been further demonstrated that the form of the oxygen can be either dissolved copper oxide, copper oxide precipitated from solid solution, or some foreign oxide in the copper. The occurrence of the cracking preferentially at the grain boundaries may be due to an accumulation of copper oxide at those points or the faster diffusion rate of hydrogen through grain boundaries than through the interior of the grain.

This report describes the experiments performed in an attempt to determine a means of controlling the intergranular cracking in shell-molded cast cones. Since satisfactory cones could not be produced using phosphorus as the deoxidizing agent, a program was designed to investigate the effectiveness of the various other deoxidizers.

Several deoxidizers are in use at the present time and the most common, in addition to phosphorus, are calcium boride and lithium. A fourth element which should be effective for deoxidation purposes in copper is titanium. No mention has been found in the literature concerning the use of this element as a deoxidizer but, from a thermodynamic standpoint the reduction of copper oxide by titanium is certainly feasible.

In addition to determining the most effective deoxidizer for pure copper shell-molded castings, part of the program was necessarily concerned with determining the type of melting equipment most suitable for producing these castings.

METHODS AND MATERIALS

Molding Practice

Two types of mold materials were used throughout this work. The first type was a shell mold used to produce a cast cone which could be examined to determine the influence of the various deoxidizers on the intergranular cracking. Conventional shell molding procedures were used in making these molds. The sand mix contained silica sand (AFS Fineness No. 120) and 5 to 6 per cent resin binder.

In order to determine whether the reactive nature of the shell mold could cause the type of embrittlement observed here, copper castings were also poured in a silica-bonded investment type mold. The materials used in this type of mold are essentially inert to molten copper and, therefore, no reaction would be expected.

These molds were used to obtain cast-to-size tensile bars (0.252-in. diameter, 1-in. gage length). The tensile data obtained from these bars were used as a measure of the relative effectiveness of each deoxidizer, and also as a comparison to the tensile properties obtained from specimens machined from several cast cones.

These molds were made using a conventional two-coat investment molding technique, using wax as the pattern material. Following a high temperature "burn-out," the molds were maintained at a temperature of 800 F until ready for use.

Melting and Casting

Three types of melting equipment were used for this work: induction equipment consisting of a 20,000 cps mercury arc converter in conjunction with a machined graphite crucible, a 3,000 cps motor generator set and clay graphite crucible, and a small gas-fired furnace. A clay graphite crucible was also used with the gas-melting equipment.

Four-pound melts of OFHC copper melting stock were prepared and deoxidized at 2300 F, with various amounts of each deoxidizer being investigated. Immediately following deoxidation, one investment tensile bar mold and one companion shell cone mold were poured. In one series of experiments utilizing calcium boride as a deoxidizer, a holding time was employed after deoxidation to allow additional time for the reaction to take place.

Deoxidation

To investigate the effectiveness of each of the deoxidizers, 0.01, 0.05, 0.10, and 0.20 per cent each, respectively, of phosphorus additions were made using a copper-20 per cent phosphorus master alloy. Similarly, titanium additions were made with a copper—50 per cent titanium master alloy. Calcium boride, in powder form, was packed in copper capsules for the deoxidation additions. The use of lithium as a deoxidizer was only investigated to a limited extent in amounts of 0.10 per cent. It was also added by packing a measured amount into a copper capsule and plunging this below the surface of the melt.

Electrical Conductivity

The effect of residual deoxidation materials on the electrical conductivity of copper was studied. Of particular interest is a comparison of the effect of titanium addition on electrical conductivity to the effects of the more commonly used deoxidizers. To obtain material for these measurements, the grip ends of broken tensile specimens were hand forged to approximately 1/4-in. diameter and subsequently swaged to a diameter of 0.09 in. These were then annealed for 1 hr at 1200 F in an argon atmosphere to remove the effects of cold work. The resistance of an 18-in. length of each specimen was measured.

RESULTS

Deoxidation

In Table 1 are recorded the results of tensile tests performed on the investment cast bars and the condition of each shell-cast companion cone. These results clearly show that neither phosphorus nor calcium boride deoxidation additions eliminate the intergranular cracking in the shell-cast cones. The tensile results from the investment-cast bars, however, show that both these deoxidizers are effective when used in conjunction with the inert investment mold.

Tensile bars cast from the melt deoxidized with

TABLE 1 – TENSILE PROPERTIES OF INVESTMENT-CAST TENSILE BARS

Mold No.	Deoxidizer Added (Wt-%)	Residual Deoxidizer (Wt-%)	Tensile Strength (psi)	Elongation in 1 in. (%)	Condition of Companion cone
		Phosphorus Deoxidation			
1	0.01	0.005	14,710	18.9	No cracking
2	None	0.005	6,260	6.4	Intergranular cracking
3	0.05	0.028	22,540	40.5	"
4	0.10	0.060	20,110	29.8	"
5	0.20	0.071	18,830	27.2	"
3A*	0.05	....	9,100	5.3	"
		Titanium Deoxidation			
6	0.01	0.005	8,950	8.1	Intergranular cracking
7	0.05	0.025	21,870	46.7	No cracking
8	0.10	0.054	23,060	38.6	"
9	0.20	0.125	20,710	28.3	"
7A*	0.05	....	23,100	32.8	"
		Calcium Boride Deoxidation* **			
10	0.01	....	7,890	8.5	No cmpn cone poured
11	0.05	....	17,040	11.6	Intergranular cracking
12	0.10	....	21,020	24.0	"
13	0.20	....	25,360	31.9	"
14**	0.05	....	20,830	29.2	No cmpn cone poured
		Lithium Deoxidation			
29	0.10	....	22,900	37.0	No cracking
245,246*	0.10	....	22,300	29.6	"

*Results obtained from tensile specimens machined from cone. Average of four specimens.
**Melt held 2 min between time of addition and pouring.
***Amounts added are expressed as per cent calcium. Analytical procedures not available for residual element determination.

0.05 per cent phosphorus had an average tensile strength of 22,540 psi, and 40.5 per cent elongation. The tensile results obtained from specimens machined from the cone poured from this heat were only 9100 psi tensile strength and 5.3 per cent elongation.

Deoxidation with titanium was much more effective than either of the above deoxidizers. Titanium additions of 0.05 per cent or more produced cones which were free of embrittlement. The tensile properties of the investment cast tensile bars poured from a melt deoxidized with 0.05 per cent titanium were 21,870 psi tensile strength and 46.7 per cent elongation. The efficiency of this element for deoxidation was also reflected in the properties of specimens machined from the cones. These gave a tensile strength of 23,100 psi and an elongation of 32.8 per cent.

In using calcium boride for deoxidation, it was noted that considerable unreacted material was left in the crucible when the melt was poured immediately after the addition. It was felt that a short holding time after the addition might be beneficial. The results of this experiment are also shown in Table 1.

Using an amount of calcium boride equivalent to 0.05 per cent calcium and no holding time, the tensile strength was 17,040 psi and the elongation was 11.6 per cent. For the same addition of calcium boride and a 2-min holding time, the tensile strength and elongation increased to 20,830 psi and 29.2 per cent, respectively.

Figure 2 is a comparison of the tensile properties and the electrical conductivity for phosphorus and titanium deoxidized copper. The data used in the plot were taken directly from Table 1. From this it can be seen that while there are no pronounced differences in the properties produced by either element, titanium appears to offer some increased

TABLE 2 – EFFECTS OF MELTING EQUIPMENT ON TENSILE PROPERTIES OF COPPER DEOXIDIZED WITH 0.10 PER CENT Li, Ti, and P

Amount of Deoxidizer Added (%)	Source of Tensile Specimen	Induction Melted 20,000 Cycle		Gas-fired Furnace	
		Tensile Strength (psi)	Elongation in 1 in. (%)	Tensile Strength (psi)	Elongation in 1 in. (%)
0.10 Li	Investment mold	22,900	37.0	25,100	35.8
	Cone casting	22,300	29.6	24,800	24.0
0.10 Ti	Investment mold	23,100	38.6	22,800	39.0
	Cone casting	23,100	27.6	24,100	30.2
0.10 P	Investment mold	20,100	29.8	20,800	49.1
	Cone casting	- - - No sound	Casting obtained - - -		

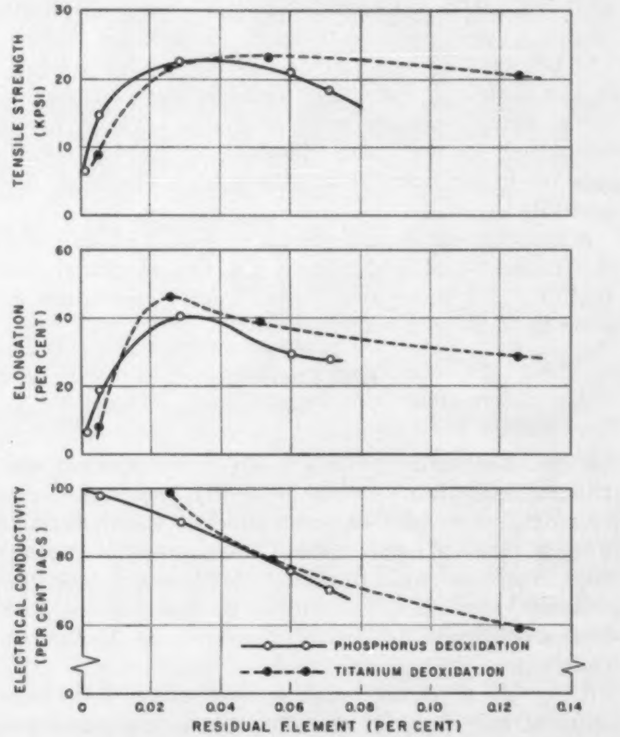

Fig. 2 – Effect of residual phosphorus and titanium on tensile properties and electrical conductivity.

benefits over phosphorus. Low residual amounts of titanium, of the order of 0.02 to 0.04 per cent, result in slightly higher elongation and conductivity values.

Effect of Melting Equipment

Table 2 is a comparison of the tensile properties of melts made by gas-fired equipment and induction-melting equipment (20,000 cps). Tensile specimens for this comparison were obtained from both investment and shell molds.

These results show that only slight differences in properties are observed for these two types of melting equipment. One type of equipment does not appear to offer any definite improvement over the other. No properties are reported for phosphorus deoxidized melts cast in the shell mold, since the castings produced again exhibited intergranular cracking. Experiments were also conducted using 3,000-cps equipment. In the experiments using the lower frequency, of which an inherent characteristic is the pronounced stirring action, considerable difficulty was encountered in producing a properly deoxidized casting.

Table 3 shows the results of conductivity measure-

TABLE 3 – EFFECTS OF RESIDUAL DEOXIDATION ELEMENTS ON ELECTRICAL CONDUCTIVITY OF PURE COPPER

Deoxidizer added (%)	Phosphorus		Titanium		Calcium Bromide*	
	Residual P (%)	Conductivity (%IACS)	Residual Ti (%)	Conductivity (%IACS)	Residual Ca (%)	Conductivity (%IACS)
0.01	0.005	98.01	0.005	....		....
0.05	0.028	90.39	0.025	99.34		98.48
0.10	0.060	76.10	0.054	78.86		100.90
0.20	0.071	70.27	0.125	57.35		100.27

*Amounts added expressed as per cent calcium. Analytical procedures not available for residual element determination.

ments made on specimens which had been deoxidized with 0.01, 0.05, 0.10, and 0.20 per cent phosphorus, titanium, and calcium (added as calcium boride). The per cent of residual deoxidizer is also indicated in the table. (No reliable methods for calcium and boron determinations were available.) These results show that, of the three deoxidizers, calcium boride appears to be best for attaining high electrical conductivity.

A comparison is also shown in Fig. 2 of the effect of titanium and phosphorus on the electrical conductivity. Of these two deoxidizers, phosphorus appears to be most detrimental.

DISCUSSION

Deoxidation

From the results of this work, it is apparent that, while deoxidation practice is highly important when pouring copper into an inert mold of the investment type, it is even more critical when using a reactive mold, such as a shell mold. Melts which are presumably deoxidized for use in the investment mold show a condition indicative of insufficient deoxidation when poured into a shell mold.

Although no quantitative measurements have been made of the composition of the reducing gases produced during the decomposition of the phenolic resin, some insight into the amount of hydrogen produced can be gained from observations of the significant amount of water vapor which condenses on a cold surface held directly above the mold immediately after pouring. The evidence presented here strongly suggests that the intergranular cracking is another manifestation of copper embrittlement by the "steam reaction."

In order to discuss the different behavior between the inert investment mold and the shell mold it is necessary to consider two reactions. First, the steam reaction

$$H_2 + Cu_2O \rightleftarrows H_2O + 2Cu \qquad (1)$$

which involves the reaction of copper oxide in the melt and hydrogen. The second reaction is

$$xM + yCu_2O \rightleftarrows M_xO_y + 2yCu \qquad (2)$$

where M is the deoxidizing agent. Using the law of mass action, the ratio of products to reactants at equilibrium can be written for equation 1)

$$K_1 = \frac{P_{H_2O}}{P_{H_2}\,[Cu_2O]} \qquad (3)$$

where P_{H_2O} and P_{H_2} are the partial pressures of the water vapor and hydrogen, respectively, and K_1 is the equilibrium constant. Similarly, the ratio of products to reactants for equation 2) can be written as

$$K_2 = \frac{[M_xO_y]}{[M]^x\,[Cu_2O]^y} \qquad (4)$$

For convenience in this discussion the terms in expressions can be rearranged as follows:

$$Cu_2O = K_3\,\frac{P_{H_2O}}{P_{H_2}} \qquad (5)$$

where

$$K_3 = \frac{1}{K_1}$$

and

$$Cu_2O = K_4\,\frac{[M_xO_y]^{\frac{1}{y}}}{[M^x]} \qquad (6)$$

where

$$K_4 = \frac{1}{(K_2)^{\frac{1}{y}}}$$

Consider a melt of copper which is ready to be poured into a mold and which has been deoxidized with a given quantity of element M. Assuming equilibrium conditions and a given pouring temperature, the concentration of Cu_2O in the melt is then given by equation 6). When this metal is poured into a shell mold, the heat of the metal decomposes the resin binder, releasing hydrogen (in addition to other gases).

Some of this hydrogen undoubtedly combines with atmospheric oxygen to form water vapor, thus producing a mold atmosphere of essentially a mixture of water vapor and free hydrogen. Again assuming equilibrium conditions and that the metal temperature remains constant after pouring, then the equilibrium relationship between copper oxide in the melt and the mold atmosphere is shown in equation 5). If the deoxidation of the melt by element M lowers the Cu_2O content below that shown in 3, then reaction 1) will not occur as written but will proceed from right to left, and the deoxidation is satisfactory.

If, on the other hand, the deoxidation leaves residual Cu_2O in excess of that shown in 3), then the reaction will proceed to the right to re-establish equilibrium, and water vapor will be formed as a result of the reaction. The amount of water vapor formed will determine whether intergranular cracking alone will occur or whether both cracking and purging will take place.

In the case of the investment mold, a reactive atmosphere is not generated since there is no resin to decompose. The ratio P_{H_2O}/P_H is large and, therefore, the equilibrium Cu_2O content is correspondingly large. Thus, it is not necessary to lower the Cu_2O content of the melt to the low level required for a shell mold.

Such was the case when, for example, phosphorus and calcium boride were used for deoxidation. The Cu_2O in the melt is reduced by phosphorus or calcium boride to a level below that required for

an investment type mold, but not sufficiently low for a shell mold. Because of this it was not possible, under these conditions, to pour a sound cone casting in a shell mold when phosphorus or calcium boride was used. * Titanium and lithium, however, are much more effective as deoxidizers. This is apparently due to these elements lowering the Cu_2O content of the melt well below the equilibrium value necessary for the steam reaction to take place.

*Presumably, both calcium and boron participate in the deoxidation reaction when used as a deoxidizer. However, as shown by the experimental work, an additional dissociation reaction must first take place before calcium or boron is available for deoxidation. In this case, there is a rate controlling reaction which may govern the effectiveness as a deoxidizer.

During the melting of pure copper, hydrogen pickup almost always occurs to some extent, depending on the products of combustion surrounding the melt. (When induction melting is used, the hydrogen source is practically negligible.) Unless this dissolved hydrogen can be removed prior to pouring, it will react with the residual Cu_2O in the melt during solidification and the water vapor formed will manifest itself in the form of porosity in the castings.

It is now almost universally accepted that copper must be melted under oxidizing conditions(6) (at least during the early stages of the melting operation). By doing this an excess of Cu_2O is provided to react with hydrogen which may have been picked up during the melting operation. This reaction is again the steam reaction, but in this instance it serves a beneficial purpose.

In general, oxidizing conditions are maintained during the early stages of melting. This is followed by a reducing stage wherein a reducing agent, such as charcoal (free of residual hydrocarbons), is added to the surface of the melt. Since the charcoal cannot remove enough of the Cu_2O, it is necessary to add additional deoxidants just prior to pouring.

Thus, in the melting of copper it appears that the steam reaction is needed during the melting operation and must be suppressed during pouring.

There is one aspect of this phenomenon which appears to warrant clarification and that is the rapidity with which the reaction takes place. The wall thickness of the cone castings is less than 0.10 in. and, therefore, cooling is rapid. The time interval during which the casting remains in the temperature range where appreciable diffusion of hydrogen can take place is relatively short.

These results indicate that sufficient time is available for the embrittlement to occur. Studies of diffusion in metals have shown that diffusion along grain boundaries may be much more rapid than through the interior of the grain.[4,5] Macroscopic examination of these cone castings has shown that the wall thickness is only several grains thick, particularly near the base of the cone. Thus, hydrogen atoms are provided "easy access" to the interior of the wall of the casting, and embrittlement could take place quickly.

Melting Equipment

It is apparent from the work dealing with the various types of melting equipment that high-frequency and gas-fired equipment are equally satisfactory for melting pure copper. On the other hand, it is exceedingly difficult, if not impossible, to use low-frequency induction equipment. The difference in melting frequency manifests itself in the degree of stirring action associated with each. High-frequency (20,000 cps) equipment produces only a slight action of this type.

Low-frequency equipment, on the other hand, produces a considerable amount of stirring action. Since the degree of stirring action is presumably the only difference, the difficulty in pouring pure copper using low-frequency melting equipment is most likely associated with the pronounced stirring action. The increased stirring action may contribute to increased oxygen pickup by the melt, and, therefore, makes deoxidation more difficult.

CONCLUSIONS

The conclusions drawn from the results of the work described in this report are:

1) As a result of the decomposition of the phenolic resin used in the production of shell molds, a hydrogen-rich atmosphere is generated within the mold cavity which is capable of producing severe embrittlement in copper castings.
2) Of the four deoxidizers investigated (lithium, titanium, phosphorus, and calcium boride) only titanium and lithium effectively deoxidize pure copper for casting into shell molds. The favorable results obtained with titanium and lithium may be due to these elements lowering the oxygen content of the melt to a level where little or no water vapor is generated by the "steam reaction" to cause rupturing at grain boundaries.
3) Both gas-fired and high-frequency (20,000 cps) induction-melting equipment are satisfactory for melting pure copper. Sound castings were difficult to produce, however, when using low-frequency melting equipment (3,000 cps). The increased stirring action associated with low-frequency equipment may contribute to increased oxygen pickup by the melt, thus making deoxidation more difficult.

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AMERICAN FOUNDRYMEN'S SOCIETY – PREPRINT NO. 58-8
This paper has been approved for presentation at the 62nd Annual Meeting of the American Foundrymen's Society, to be held in Cleveland, Ohio, May 19-23, 1958. The Society reserves all rights for publication either prior to or subsequent to presentation, and is not responsible for statements or opinions advanced herein.
WRITTEN DISCUSSION IS SOLICITED

MOLD SURFACE BEHAVIOR

By

Dan Roberts and Earl E. Woodliff**

ABSTRACT

The paper introduces a new method of studying molding and core sand expension by pouring metal around the standard 2-in. dia. x 2-in. long test specimen. Illustrations of the simple equipment used in these investigations, as well as much plotted data, are provided.

Factors involved for the control of sand expansion have been found associated with moisture, clay content, combustibles, pouring temperatures, grain distribution and fines content. Each of these are dealt with separately, serving to show how one foundry has arrived at a completely stable and expension-free sand. A method of interpretation of test data, based on initial expansion and rate or average expansion in the early period of the tests, has enabled the authors to predict the sands behavior in the molds.

While much of the test has been conducted with gray iron, data are included on some tests made with steel. Included is one foundry sand completely out of control, shown mainly to compare with a controlled sand and what may be gained through tests and study.

The authors do not claim this to be a scientific study with great accuracy, but one which every foundryman can afford to use to improve his sands at low cost.

Examinations of a mold shortly after pouring shows many cracks, and in rigid flask molds a tendency to push the sand up and out of the flask. All indicate that there is growth and movement to the rammed mold. Since all metals contract on cooling, the cause of this growth can be assumed as expansion of the mold due to temperature rise from heat given up from the casting.

Measurement of thermal growth or expansion of a rammed sand has been possible for at least 25 years. The method described here was developed by the authors mainly because of the need for more information as to mold surface behavior, and a limited budget. Since casting of metal into sand molds is the natural cause of sand expansion, it seemed logical that this growth when measured would be more informative than straight radiation heating as in case of the dilatometer furnace. In addition, perhaps the casting after cooling would reveal surface defects for a direct correlation with expansion. For the past 7 years the Oil City Iron Works has been making extensive tests (both research and control) which enables this publication, and with a definite improvement in their production and quality.

*Oil City Iron Works, Corsicana, Texas.
**Foundry Sand Engineer, Detroit, Mich.

The Instrument

While the instrument design was worked out at another foundry during the war, due to lack of time not enough data were accumulated to make the instrument a commercial possibility. The later instrument, as built by the Oil City Iron Works for these studies, embodied some definite improvements. It is reasonably simple in design, very inexpensive, portable, and has proved to give a high degree of duplication on subsequent testing.

It consists of four principal parts; namely, the welded metal frame, a pouring basin type core and its core box, a 1/2 x 12-in. stem chaplet which has been both center drilled and machined on its face to be smooth and 90 deg to its stem. In addition there is the micrometer dial indicator.

A sketch of the instrument assembly is shown in Fig. 1, and a photograph (Fig. 2) shows the assembly ready to make a test run. The frame consists of a base with recessed top in which sand is loosely packed and struck off level. The base, too, is machined to assist in keeping the instrument level during the testing. The side arms and top cross member are simply for rigid support of the micrometer dial indicator. This is secured through a pillar block and stud with clamping screw. Thus, up-and-down adujstment of the indicator dial can be made. An insulated heat shield is provided to protect the instrument and top cross member from radiant heat during tests.

The more important part of the instrument's construction is the core or core mold (Figs. 3 and 4). Each test consumes one of these cores. An aluminum core box has been designed to provide in the core three important features:

a) A pouring basin amply large to receive metal from a bull ladle.
b) A dam between the pouring basin and test casting with under feed gates to eliminate metal turbulence in the test casting section during pouring.
c) A flow-off of the exact height to bring the test casting surface to within 1/32-in. of specimen top.

The core is produced from oil-bonded core sand and baked. These cores usually are made on work orders of 24 at a time, and repeat runs use the same core mixture, thus providing a minimum of differences from test to test. Cores are stocked close to core ovens to assure uniformly dry cores.

Care is necessary in locating the core on the sand bed prior to making a test to assure exact alignment

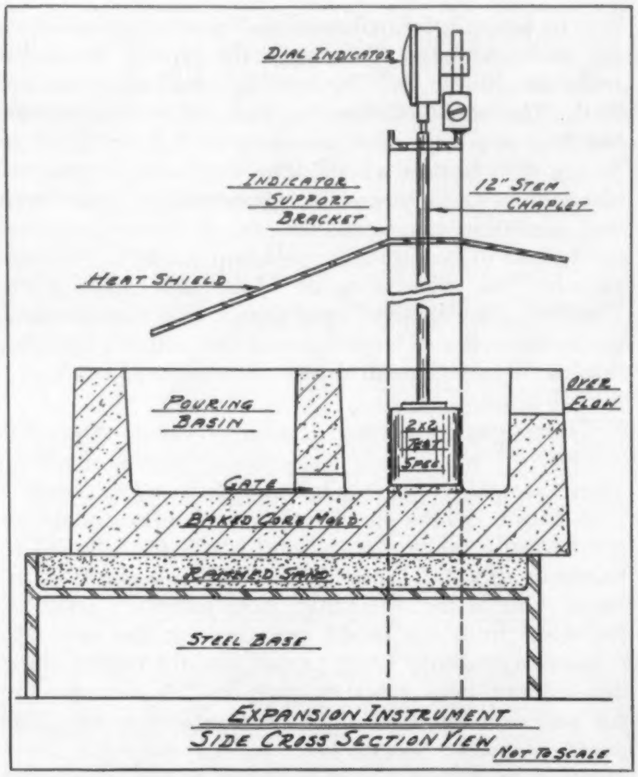


Fig. 1 — Sketch of complete instrument assembly as set for expansion test.

between test specimen and indicator dial. This must be within 1/8-in. in either direction.

The contact between test specimen and dial indicator is a standard 1/2 in. x 12 in. chaplet, the stem end having been countersunk with a drill sufficiently to provide a machined surface for dial indicator contact point. To provide a full seat of the chaplet head on the test specimen, the chaplet head is turned smooth and at 90 deg with its stem. Life of these stems has been good, but they require periodic replacement. The top cross member has a recess opening through which the stem projects contacting the Federal type, long travel dial indicator.

TESTING PROCEDURE

In the study of mold surface behavior the standard AFS 2 in. x 2 in. test specimen is used, except that all test specimens are oven dryed in the case of molding sands or baked in case of cores. Drying is at 230 F for a minimum time of 2 hr. In preparation for making the test a thin coating of core paste is placed on the specimen pedestal of the test core mold. As the hot dried test specimen is removed from the drying oven it is immediately placed and secured by the paste. It is weighted down and allowed to cool. Several such test core molds with different test sands are usually prepared to enable more than one test during one heat period.

The instrument and prepared test molds are carried to the foundry floor. The instrument is made level, sand bed packed and struck off, and a pig bed made at the back to receive flow-off metal. The test core mold is then placed in such a manner on the sand bed as to give alignment between specimen and dial

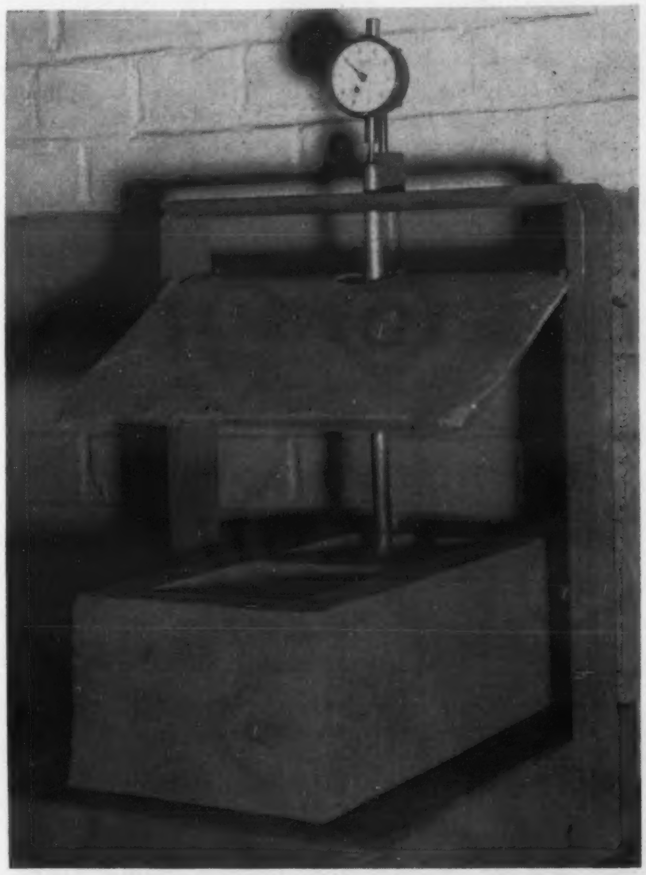


Fig. 2 — Expansion meter set up ready for use. Note simplicity and portability.

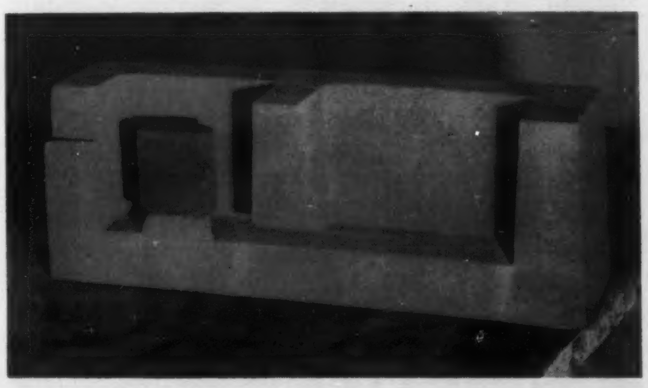


Fig. 3 — Baked core sand mold cut thru lengthwise showing 2 in. dia. x 2 in. long test specimen pasted in place.

Fig. 4 — Baked core mold showing top view and flow off at right end.

indicator. When the stem chaplet is in place the contact point of dial indicator should be centered and free. A check of this is made by raising the contact point several times, observing if dial reading returns each time to "0" setting. A usual adjustment of contact point is to give 0.010 to 0.020 in. above "no-load" position, thus, assuring complete contact at start. The dial face, however, is always set at "0" setting.

Metal is brought direct from cupola assuring a fairly uniform temperature iron. Tests have shown higher temperature metals to be more active in bringing out the mold surface behavior and, after experimentations at the foundry, the pouring of tests was established at the 2700 F level. Figure 5 shows curves where three temperature ranges of metal were cast against the same type of sand specimen. These curves A, B and C, are parallel. So far as rate of expansion goes they are identical. Metal temperatures are read by optical pyrometer.

Pouring of the test mold is at a rate similar to that for snap molds. But the timing of test with stop watch is not started until movement of dial indicator pointer is noted, thus, giving "0" growth at "0" test time. Iron is poured into the basin until some has overflowed into the pig bed. Loose dry sand is then thrown over the basin and pig overflow to protect the operator and instrument from heat.

Reading of expansion is taken at 15-sec intervals for first minute, 30-sec intervals through 3 min, then at minute reading until curve reaches maximum, usually 10-12 min. Since expansion readings are for a 2 in. long specimen, they are divided by two and expansion in in./in. obtained. Many test runs are plotted as on accompanying curves. However, after many tests this procedure is unnecessary since rate of expansion can be calculated from data without need for curves. Essential data relating to the sand is always made a part of the records and through this accumulated information and test method the foundry has arrived at certain safe operating limits for molding and core sands. These control points have been developed through a correlation of casting results and test results. It is well to point out that while they work exceptionally well at the author's foundry, they might well have to be adjusted for any other foundry. The three most important readings made during this test are; one and 4 min and then the maximum point which usually comes between the 10- to 12-min readings.

TEST DATA AND FACTORS EFFECTING CHANGES

Measurement of sand expansion by casting metal against standard AFS specimens made from it have shown eight contributing factors which must be taken in account to control expansion defects, listed as follows:

1. Clay content
2. Distribution of grains
3. Fines, i.e., minus 140 grains
4. Combustible content and types
5. Rammed density
6. Pouring temperature of metal
7. Pouring rate
8. Type of base sand (purity and grain shape)

All can be varied, with some lending themselves to change more readily than others. Combustibles and clay content of the sand can be changed over night, as well as pouring temperature and pouring time which are easily adjusted. To change the type of sand, distribution, "fines" and density requires both time and study. Therefore, an effort has been made to determine the best available type of sands and their blend to give a distribution which produces lower expansion. Since "fines" influence sand expansion their maximum and minimum range was studied to determine what safety had to be built into molding sands to compensate for "off" conditions of "fines" and distribution. The four controls over sand defect due to expansion, are in this order of importance at the author's foundry, due to improved control over melting and sand;

1. Pouring temperature
2. Combustibles in sands and types used
3. Pouring rate
4. Clay content of sands

These are the controls necessary on per job bases.

In Fig. 6, which shows expansion curves made on synthetically bonded snap sand heaps conditioned to facing quality, the three curves show two points of interest. One is the effect had from adjusting combustibles up from 3.0 to 4.1 per cent on the one min expansion reading. Long period casting results show the 3.0 per cent sand to give rat-tail defects, the 3.6 per cent sand to spall or cope down on some heavy squeezer work, and the 4.1 per cent sand seems to be safe for fairly heavy castings. The second interesting point is made by comparing these light snap sands with the heavier main bay sands, where:

a) 4.1 per cent combustibles in an 8 per cent clay sand produces close to same "initial" or one-min expansion, as does 10.6 per cent combustibles in an 11.4 per cent clay sand (Figs. 6 and 7).
b) The control point of 0.025 in./in. is ample and safe for this sand; as long as the curves remain below this reading at one min, good results usually are obtained.

In dealing with factors in the main bay work we first take up pouring temperature. These curves *A*, *B* and *C* (Fig. 5) show increase in sand expansion of a heavy naturally bonded Tennessee type sand,

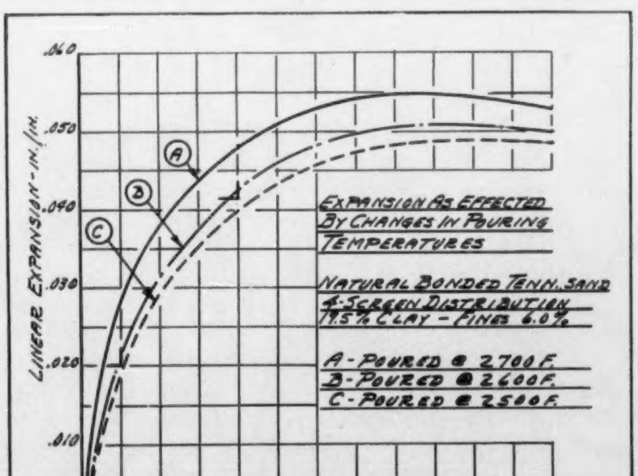


Fig. 5 – Expansion of a single type sand varies as the pouring temperature with the higher temperature metal causing the higher expansion.

clay 19.5 per cent, 4-screen distribution and "fines" content 6 per cent, as pouring temperature is increased from 2500 to 2700 F. With the two established controls limits for heavy sand at 0.020/1-min and 0.042/4-min, this would be a safe sand when molds are poured between 2500-2550 F, but too high an expansion for higher temperatures. The rate of expansion is obtained by the following calculations:

$$\frac{\text{Indicator Dial Rdg. (4-min)} - \text{Indicator Dial Rdg. (1-min)}}{6}$$

$$\text{or,} \quad \frac{\text{Expansion (4-min)} - \text{Expansion (1-min)}}{3}$$

= Rate or average expansion between one and 4 min. Readings are in./in./min.

In the case of varying pouring temperatures with the same sand this rate of expansion shows a constant value of 0.0065. When considered along with the control point or one-min expansion this rate of expansion indicates the behavior of the mold surface. At the foundry where tests were made the main floor sands are safe when conditions are controlled to give one min expansion at or below 0.020 in./in., and a rate of expansion at or below 0.0073 in./in./min. Table 1 shows readings of importance, for all curves, and rate of expansion.

Considering next grain distribution and combustibles of heavy sand, skin dried molds (Figs. 7 and 8), we find Curve "A"–3-screen sand (Fig. 7) with 10.2 per cent combustibles to produce buckles, whereas

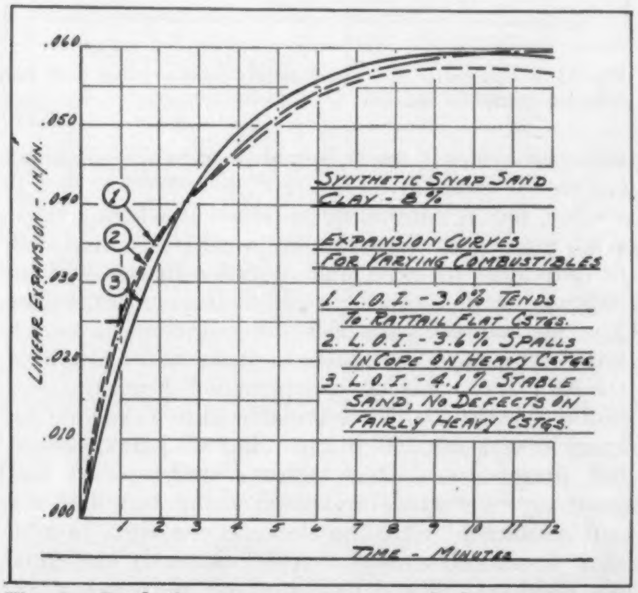


Fig. 6 –Synthetic snap or squeezer sand showing how the initial (1 min) expansion can be varied with varying percentage of combustibles.

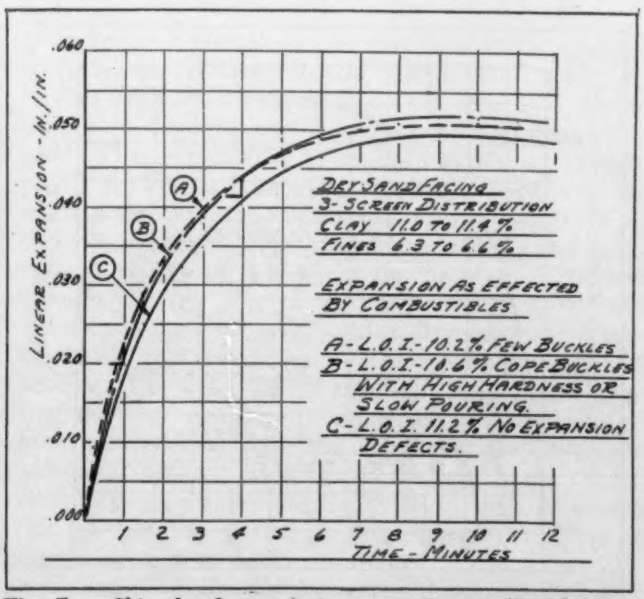


Fig. 7 – Skin dry heavy facing expansion studies showing variations necessary when the sand is only a three-screen distribution.

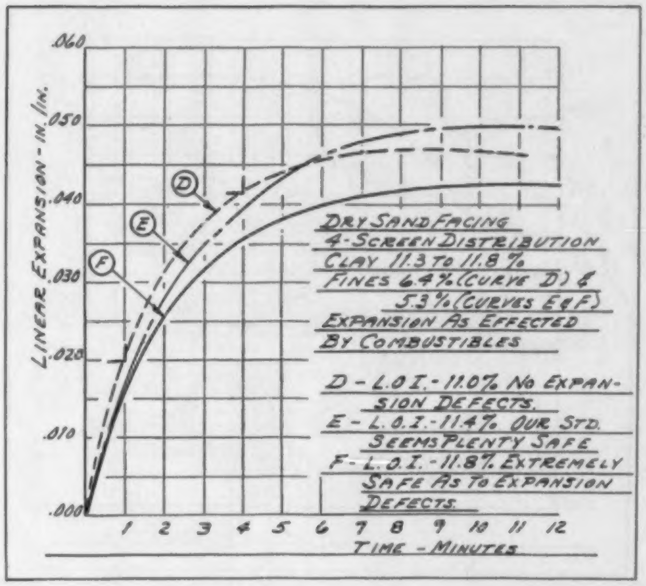


Fig. 8 – Skin dry heavy facing expansion studies showing improvements had by a four-screen distribution and reduction in fines.

TABLE 1 – LISTING IMPORTANT EXPANSION READINGS AND CALCULATED RATE OF EXPANSION FOR CURVES ACCOMPANYING THIS REPORT.

Fig. No.	Curve Designation	Initial Expansion, (1-min) in./in.	4-min Expansion, in./in.	Max. Expansion, in./in.	Calculated Avge. or Rate of Exp., in./in./min.
5	A	0.0285	0.048	0.055	0.0065
	B	0.022	0.0415	0.051	0.0065
	C	0.0195	0.039	0.049	0.0065
6	1	0.027	0.047	0.0575	0.0067
	2	0.0255	0.0485	0.0600	0.0077
	3	0.0218	0.050	0.0595	0.0127
7	A	0.0225	0.044	0.051	0.0073
	B	0.022	0.044	0.052	0.00735
	C	0.020	0.0405	0.0495	0.0068
8	D	0.021	0.042	0.0465	0.0070
	E	0.018	0.039	0.050	0.0070
	F	0.0185	0.0355	0.043	0.0056
9	T	0.022	0.048	0.055	0.0086
	S	0.0155	0.035	0.0435	0.0065
10	A	0.0245	0.0458	0.059	0.00704
	B	0.0205	0.0375	0.048	0.0056
11	D	0.026	0.044	0.053	0.0060
	C	0.0235	0.040	0.043	0.0055
12	2	0.0325	0.052	0.0565	0.0065
	3	0.032	0.047	0.049	0.0050
13	1	0.0305	0.0565	0.069	0.0086
	2	0.0315	0.0560	0.0685	0.0081
	3	0.0295	0.0535	0.0630	0.0080
14	1	0.026	0.049	0.060	0.00767
	2	0.019	0.037	0.0425	0.0060
15	1	0.018	0.041	.....	0.0077
	2	0.013	0.030	.....	0.0057
	3	0.0105	0.028	.....	0.0058
16	1	0.0315	0.0542	.....	0.0076
	2	0.0275	0.0475	.....	0.0067

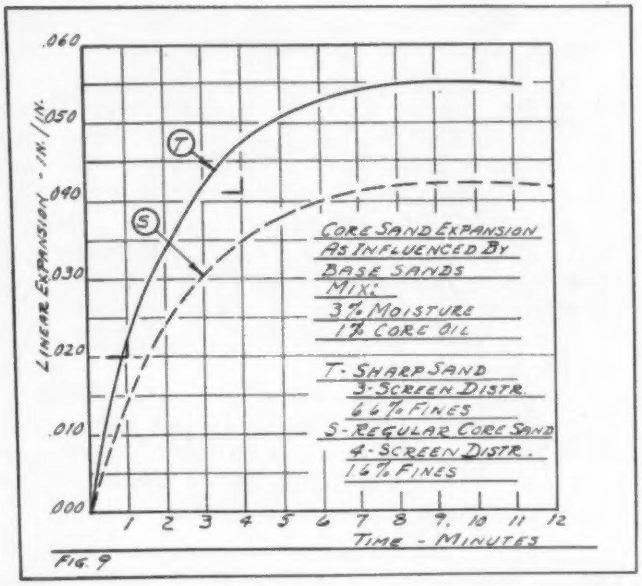


Fig. 9 – Expansion studies of two local core sands; oil bonded and baked.

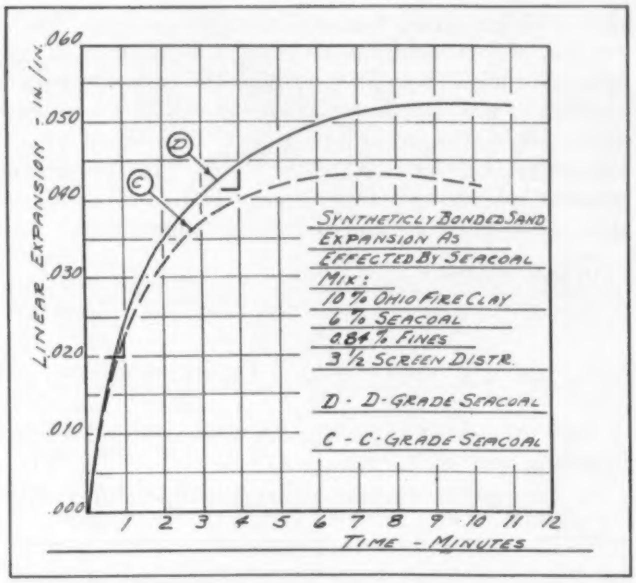


Fig. 11 – Expansion of a synthetically bonded sand with two different grinds of seacoal.

Curve "C" with same distribution is safe with 11.2 per cent combustibles. Curve "D" (Fig. 8) shows a four-screen distribution sand at 11.0 per cent combustibles as also safe. Curve "E" is the standard type sand for heavy work. When "fines" are reduced from 6.0-6.5 per cent to 5.3 per cent, Curve "F", the sand is extremely safe, allowing the making of flat counterweight castings of 6-in. cross sections and 15-sq ft flat cope area with pouring temperature of 2550 F at a pouring rate of 30 lb/sec. While the sand no doubt is stabilized for 2700 F pouring, the lower casting temperature is used for added safety. Distribution, as shown, only adds safety.

When the combustibles are in close range, going from a three-screen distribution to a four-screen sand is hardly an improvement (Curves "C" (Fig. 7) and "D" (Fig. 8). Change in distribution as to "fines" content, with a reduction showing the better control curve, indicates this portion of the sand grain distribution curve does influence expansion, reference Curves "E" and "F" (Fig.8).

Clay, too, is considered an element which reduces sand expansion. Regular clay wash tests are made to determine its level and in order that it will not become low and adversely add to the sand expansion. The method used for this determination is one to give "Actual Clay" as different from AFS Clay. First, the AFS Clay wash loss is determined. From the wash bottle base the grains are transferred to a crucible and burnt over a hot gas burner until all black (carbon) has disappeared. Thus, washed and ignited sand grains are obtained for screen sizing test and clay and combustibles are the elements removed. In addition, a second sample of original sand, unwashed, has been ignited and loss obtained, thus making the calculation of true clay possible;

Clay (wash) + Loss on Ignition (of Washed

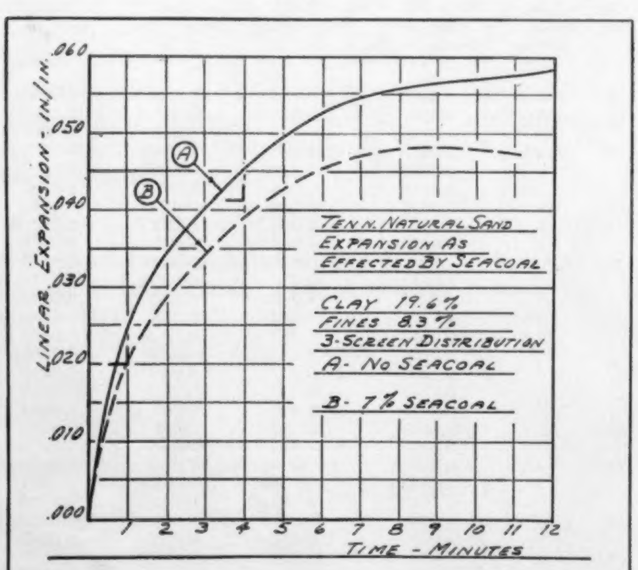


Fig. 10 – Expansion of a natural bonded Tennessee molding sand with and without seacoal.

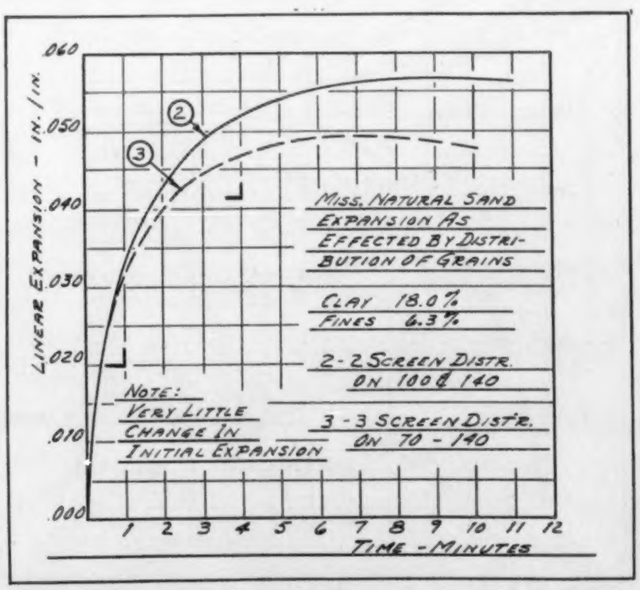


Fig. 12 – Expansion of incoming natural molding sand as varied by distribution of grain.

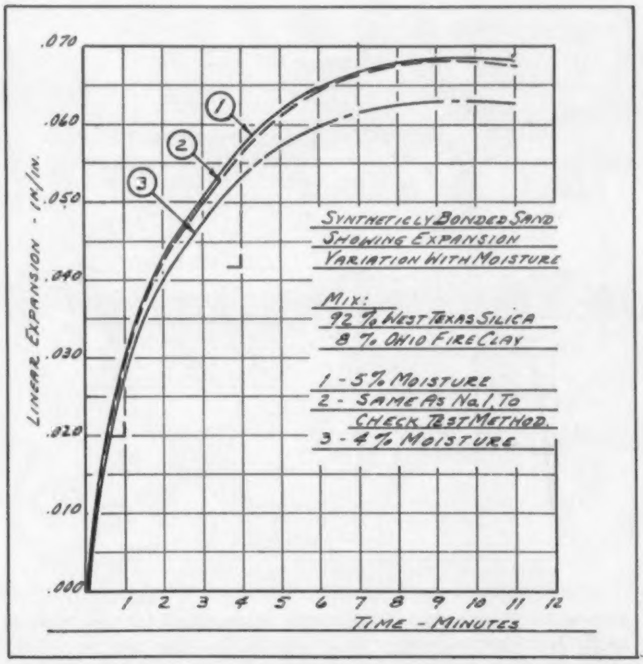


Fig. 13 – Expansion of a clay bonded sand at two different levels of moisture content.

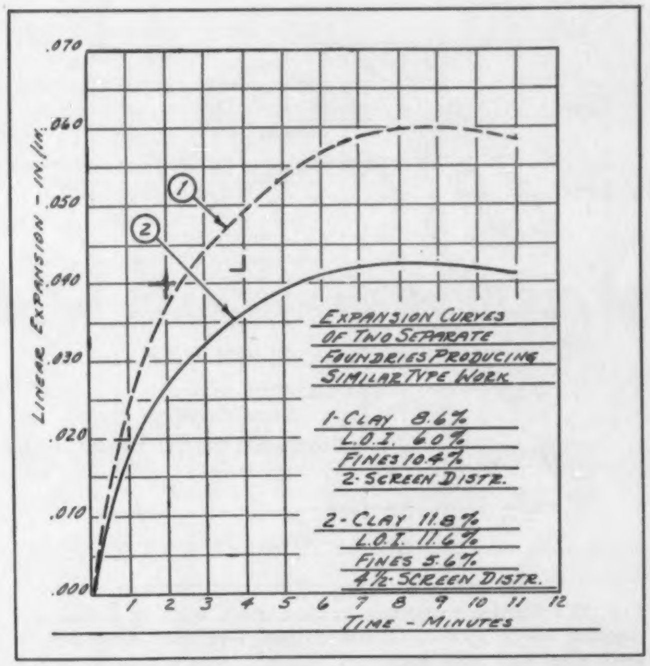


Fig. 14 – Expansion curves of sands from two separate foundries showing the results of a stabilized expansion as compared to an uncontrolled sand.

Grains) – Loss on Ignition (of Unwashed Grains)
= True Clay Substance

The clay contents reported herein are results as calculated for true clay. Loss on ignition are results from igniting the dried unwashed grain.

USE OF EXPANSION METER FOR SEPARATE STUDIES

Following the practices outlined for control purposes, many separate studies have been made to determine the sand behavior when one property was varied for a single study. The authors feel they show properties of academic interest. It is used to check incoming raw materials as against previous supplies at the author's foundry.

Reference is made to the curves for these separate studies, as they show clearly the problem in each instance:

Figure 9–A comparison of two local sands used for coremaking, oil bonded and baked. One sand "T" having high expansion at both the one- and 4-min. expansion, together with high rate of expansion, while sand "S" is satisfactory since both expansion control points are low as is its expansion rate. Since both are white silica sand some of the reasons believed to effect these differences are given as fines contents and grain spread. The two sands are of similar grain shape and fineness.

Figure 10–A naturally bonded Tennessee sand tested in its raw condition and with the addition of seacoal. The behavior of the sand before and after this addition enables the operating foundrymen to view for the first time the beneficial properties obtained by seacoal additives in lowering sand expansion throughout the pouring cycle as well as during the solidification period of the castings. The rate of expansion is greatly influenced.

Figure 11–Here are shown two synthetically bonded mixtures of the same base sand and 10 per cent, (by weight) of fireclay bond, with their difference being in the type of seacoal used. One sand, Curve "D", containing 6 per cent (by weight) "D" grade seacoal, and the other sand, Curve "C", containing 6 per cent of "C" fineness seacoal. Difference in seacoal fineness affecting burning rate enables the coarser grind to remain an active expansion control element over a longer period, an essential factor in making heavy castings in green sand molds.

Figure 12–A natural sand having a two-screen distribution compared with a similar sand, as to clay and "fines" content, but having a three-screen distribution. While both sands are without additives and are above the safe control points the one with wider difference of grain sizes has the lower rate of expansion and upper (4-min) expansion value. Since fines and clay were not changed the lower (1-min) expansion point showed little or no change.

Figure 13–Moisture variation is shown here for an 8 per cent fireclay bonded sand, no additives other than water. Curves 1 and 2 are both at 5 per cent moisture, while Curve 3 was tempered with 4 per cent moisture. The 5 per cent moisture sand was tested twice to show the ability of the test to give duplicate data. In a prepared sand which closely falls in the safe range, one can view how excess moisture might well be one of the causes which produce expansion defects.

Related to this moisture difference is the rammed density of each sand. With the higher moisture level a density of 115 lb/cu ft was recorded as compared to 100.7 lb for the 4.0 per cent sand. This may account for difference in expansion for with constant density rammed specimens the curves are similar.

Figure 14–Shown here are two entirely different sands, as to base grain, bonds used, loss on ignition, clay contents, fines and distribution of sand grains. Both foundries are producing some similar type castings, but with different end results. We believe the

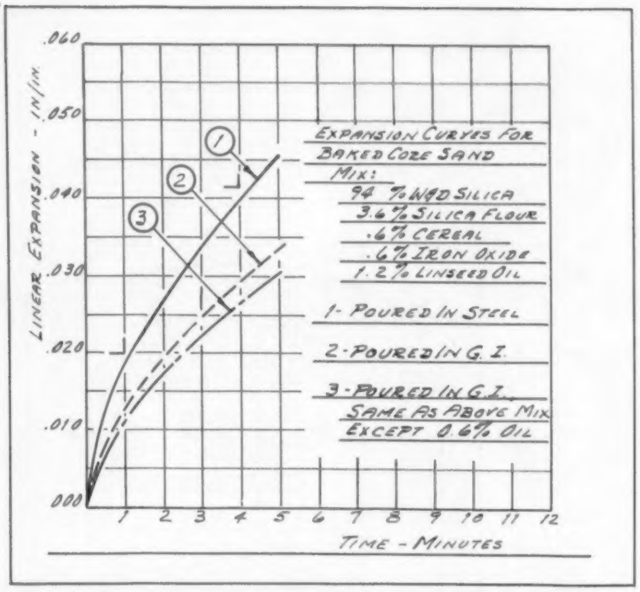


Fig. 15 – Earlier expansion studies made with a similar expansion meter showing a baked steel type core sand cast in both steel and gray iron.

justification for the great amount of work done in these studies is largely shown in this single comparison.

After assembling the above information from the files of the Oil City Iron Works, the authors applied the same control factors to expansion data obtained as early as 1944. These studies were made on a similar expansion meter but due to lack of sufficient information to interpret them have not been published until this time. They embody sand behavior under conditions of pouring both with gray iron and with steel. Surprising as it may seem, the control points established by Oil City Iron Works applies equally well to the earlier test.

In reference to a core sand (Fig. 15) made for use in armor plate, we find the expansion safely within the control limits but high in rate of expansion when poured in steel. The same sand poured in gray iron is amply safe at all control points. A similar core mixture, but with one-half the amount of linseed oil, shows lower expansion (Curve 3, Fig. 15). Explanation for the higher expansion of the sand poured in steel than that in gray iron seems to be in the difference in pouring temperatures.

Two facing sands made for armor steel showed expansion defects and were well above the safe limits (Fig. 16). Facing (Curve 1) containing no stabilizer material, while facing (Curve 2) contained 0.9 per cent cereal and showed lower expansion and a much improved rate of expansion. These data are inconclusive as it is indicated safety can be had in steel sand by control over mold surface behavior.

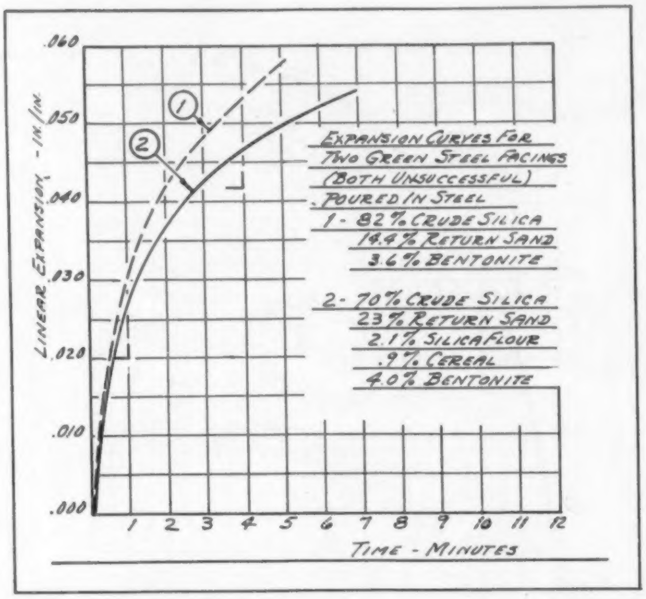


Fig. 16 – Expansion of two steel green sand facings, cast in steel, and the reduction of expansion by the use of cereal.

CONCLUSIONS

1) The simple measurement of sand growth as metal is cast around it offers the interested foundryman a means of control over the many casting defects caused from its expansion.

2) It is possible to predetermine the behavior of a sand as to its expansion characteristics by control over the several factors contributing to its expansion. Judgment should be exercised as to which factor is best means of control as to each individual foundry.

3) The control limits established here apply only to the several sands and their binders. However, means are offered whereby one can work out satisfactory control for other sands.

4) Factors which have been found mostly influencing sand behavior are:
   A. Type of sand grain
   B. True clay content
   C. Distribution of grains
   D. Fine content
   E. Combustibles type and content
   F. Pouring temperature
   G. Pouring rate
   H. Rammed density or hardness

5) While all defects are not from sand expansion it is the conclusion of the authors the expansion meter offers a distinct advantage in control of the many causes of mold wall movement. Through this control one foundry has greatly improved its quality and production of castings.

AMERICAN FOUNDRYMEN'S SOCIETY – PREPRINT NO. 58-25

This paper has been approved for presentation at the 62nd Annual Meeting of the American Foundrymen's Society, to be held in Cleveland, Ohio, May 19-23, 1958. The Society reserves all rights for publication either prior to or subsequent to presentation, and is not responsible for statements or opinions advanced herein.

EVALUATION OF SHELL MOLDING PROCESS CAPABILITY

By

W. C. Truckenmiller,* C. R. Baker,* and G. H. Bascom*

ABSTRACT

Procedures, specific results, and conclusions from investigations for the evaluation of dimensional control capabilities of the shell process are reported. Both external shells and shell cores are considered. Sampling procedures for the development of critical pattern dimensions are outlined.

INTRODUCTION

Development of shell molding has given to the foundry industry a process by which more accurately dimensioned molds and, hence, more accurately dimensioned castings are possible. The degree of improvement varies with the material being cast, the size and complexity of the casting, the pattern layout, and the details of operating procedure.

During the development of the shell molding process, many claims and counterclaims have been made on the subject of attainable dimensional accuracy. A considerable number of these have appeared in the recent literature. It is not our purpose, however, to either substantiate or refute such past claims, but rather to outline a procedure followed at the authors' company for establishing attainable tolerances on certain castings or casting dimensions. From such information, pattern corrections can be intelligently undertaken, and sampling procedures can be instituted to determine adherence to customer specification. Specific numerical values together with pertinent information on casting size, shape, and treatment, as well as significant details of operating procedure will be given.

It should be evident that the procedures set forth in the subsequent discussion are equally applicable to all types of shell-molding operations, but that exact numerical values of some deviations established here are essentially unique to the individual applications.

DIMENSIONAL CONTROL OF AN AUTOMATIC TRANSMISSION PART

It was decided to first make a general process evaluation by measuring certain significant diametral dimensions and a dimension across the parting of an automatic transmission part shown in Fig. 1. This part, weighing approximately 9 lb was produced in

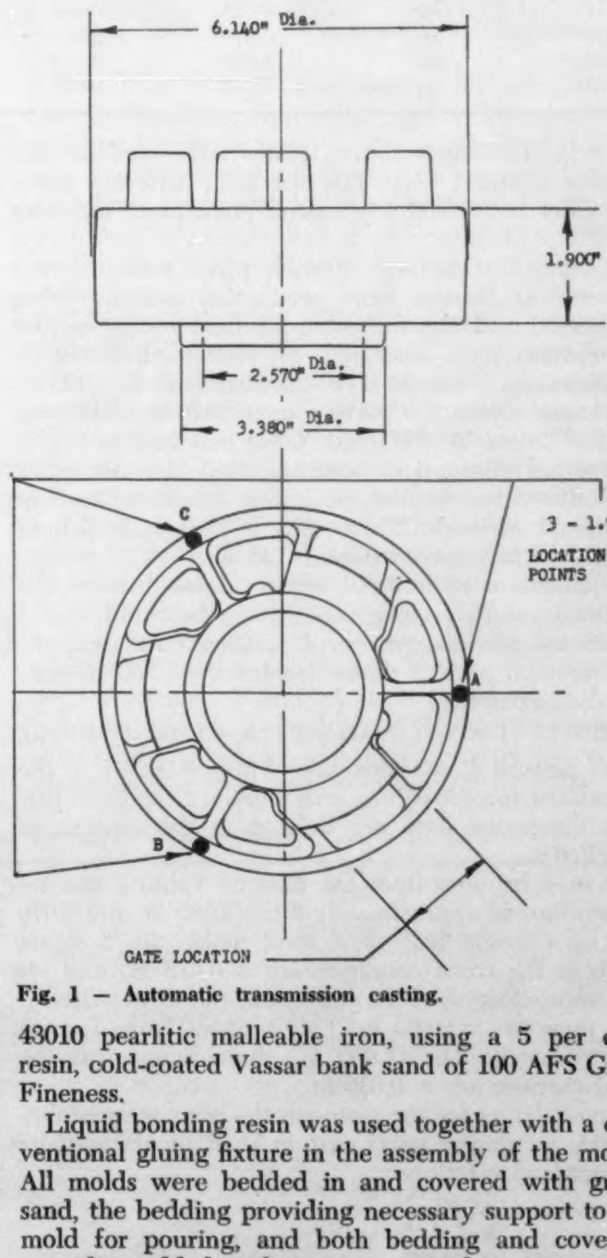


Fig. 1 – Automatic transmission casting.

43010 pearlitic malleable iron, using a 5 per cent resin, cold-coated Vassar bank sand of 100 AFS Grain Fineness.

Liquid bonding resin was used together with a conventional gluing fixture in the assembly of the molds. All molds were bedded in and covered with green sand, the bedding providing necessary support to the mold for pouring, and both bedding and covering providing added cooling rate required to prevent primary graphitization at the mold surfaces during solidification. Both cope and drag of a four-on mold were produced on a 20 × 30 in. pattern plate with a break-

*Assistant Technical Director, Chief Pattern and Tool Engineer, and Project Supervisor, respectively, Albion Malleable Iron Company, Albion, Michigan.

TABLE I – AVERAGE DIMENSIONS AND THREE SIGMA LIMITS FOR AUTOMATIC TRANSMISSION CASTING

Calculated Values at the Following Nominal Dimensions

Piece No.	Calculated Value	3.380	2.570	6.140	1.900 (A)	1.900 (B)	1.900 (C)
13	$\overline{X}$	3.365	2.564	6.114	1.896	1.895	1.900
13	3σ	0.015	0.012	0.016	0.030	0.021	0.022
14	$\overline{X}$	3.381	2.573	6.112	1.897	1.896	1.901
14	3σ	0.015	0.018	0.024	0.024	0.018	0.018
15	$\overline{X}$	3.376	2.576	6.107	1.907	1.900	1.906
15	3σ	0.018	0.012	0.024	0.021	0.024	0.027
16	$\overline{X}$	3.373	2.570	6.118	1.900	1.896	1.905
16	3σ	0.015	0.012	0.021	0.012	0.018	0.027
17	$\overline{X}$	3.377	2.574	6.117	1.892	1.893	1.891
17	3σ	0.015	0.018	0.018	0.009	0.009	0.012
18	$\overline{X}$	3.370	2.567	6.115	1.898	1.900	1.898
18	3σ	0.012	0.015	0.021	0.021	0.018	0.015
19	$\overline{X}$	3.361	2.549	6.097	1.885	1.879	1.881
19	3σ	0.018	0.018	0.024	0.018	0.018	0.024
20	$\overline{X}$	3.370	2.568	6.108	1.897	1.893	1.901
20	3σ	0.018	0.012	0.021	0.015	0.012	0.027
All	3σ Max.	0.018	0.018	0.024	0.030	0.024	0.027

er strip. Two such pattern plates were used for the results reported here; the first plate carrying piece numbers 13-16, and the second plate piece numbers 17-20.

Twenty-five castings of each piece number were selected at random from production castings being processed and the following nominal rough casting dimensions were measured: 1) 3.380-in. diameter, 2) 2.570-in. diameter, 3) 6.140-in. diameter, 4) 1.900-in. thickness across the parting measured at machining locator points "A", "B", and "C" as indicated in Fig. 1.

Average dimensions and standard deviations for each dimension on each piece were calculated by conventional methods. The results of these calculations are shown in summary form in Table I.

Application of a 0.010 in./in. shrink rule to the nominal rough casting dimensions shown in Fig. 1 yields the nominal pattern dimensions. For example, the nominal pattern dimension for the 1.900-in. casting dimension is:

$$(0.010)\ (1.900) + 1.900 = 0.019 + 1.900 = 1.919 \text{ in.}$$

All pattern dimensions were within 0.002-in. of the calculated correct values, and therefore complete pattern dimension data are deleted in the interest of simplicity.

It may be seen from the data of Table I that on dimensions of approximately 3 in. (3.380 in. and 2.570 in.) in a single half of a shell mold, the 3 sigma limits of the worst condition are ± 0.018 in., and for the approximately 6 in. maximum (6.140 in.) dimension they are ± 0.024 in. The 3 sigma limits for the approximately 2-in. (1.900 in.) dimension across the mold partings are ± 0.030 in.

Generalizing for the moment, the process capability on this or similar parts cast in shell molds may be summarized as follows:

Approximate Dimension, in	Within Mold Half or Across Parting	3 Sigma Limits	2 Sigma Limits
3	Within	±0.018	±0.012
6	Within	±0.024	±0.016
2	Across	±0.030	±0.020

With expected normal distribution, 99.7 per cent of all castings will fall within the 3 sigma limits and 95.5 per cent of all castings will fall within the 2 sigma limits.

The advantages of the shell molding process for this particular type of part are multifold. First, there is potential saving in metal removal by machining because of known closer tolerances compared to sand casting. Second, since this is a part which must be statically and dynamically balanced, the more uniform size and shape made possible by the shell process materially aid the balancing operations, reducing

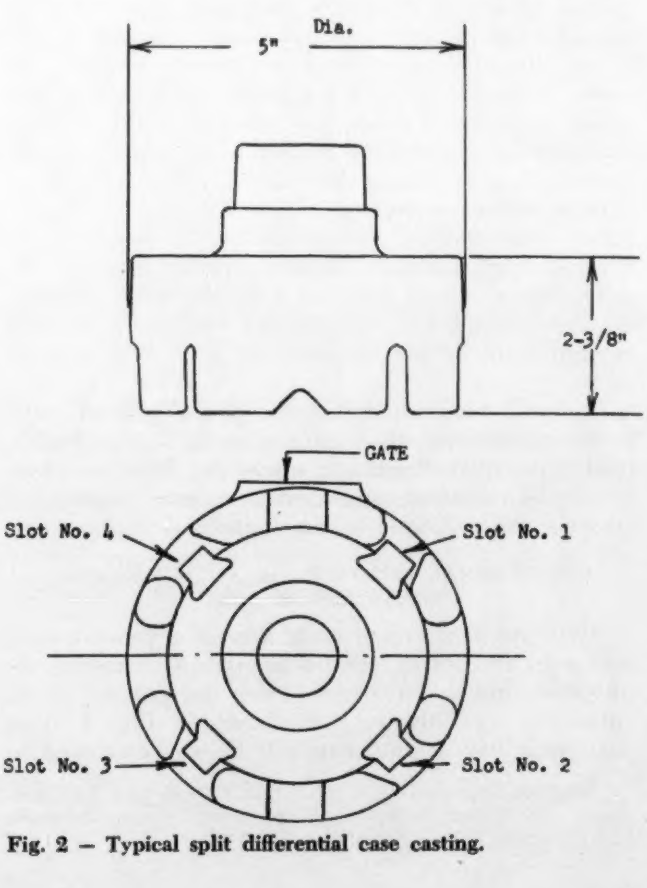


Fig. 2 – Typical split differential case casting.

TABLE 2 – DIFFERENTIAL CASE "A" INITIAL TEST

Piece No. 1

Slot No.	Pattern Dimension	Mean Dimension $\overline{X}$	Standard Deviation	Average Range	For Sub-Group of 5 $UCL_{\overline{X}}$	$LCL_{\overline{X}}$	UCL_R	LCL_R
1	0.488	0.4822	0.0019	0.0044	0.4848	0.4796	0.0093	0
2	0.488	0.4822	0.0017	0.0039	0.4848	0.4796	0.0082	0
3	0.487	0.4824	0.0017	0.0039	0.4847	0.4801	0.0082	0
4	0.487	0.4821	0.0013	0.0030	0.4838	0.4804	0.0063	0

Piece No. 2

Slot No.	Pattern Dimension	Mean Dimension $\overline{X}$	Standard Deviation	Average Range	For Sub-Group of 5 $UCL_{\overline{X}}$	$LCL_{\overline{X}}$	UCL_R	LCL_R
1	0.492	0.4880	0.0012	0.0028	0.4896	0.4864	0.0059	0
2	0.489	0.4855	0.0021	0.0049	0.4884	0.4826	0.0103	0
3	0.489	0.4848	0.0010	0.0023	0.4861	0.4835	0.0049	0
4	0.487	0.4834	0.0019	0.0044	0.4850	0.4808	0.0092	0

both time and cost. Third, and probably most significant, the greater uniformity of dimension of these castings better meet the exacting requirements of the increasingly used automated, multiple machining operations on high production automotive parts. It is in the area of this last-mentioned item that shell molding generally offers one of its most important advantages over less precise casting methods.

DEVELOPMENT OF PATTERN DIMENSIONS

A completely different problem presented itself in the development of pattern equipment for shell molding of split differential cases, a typical example of which is shown in Fig. 2. In the development of a whole series of these castings, it was necessary to hold the width of each of four slots in each casting to 0.510 in. ± 0.010 in. No previous experience was available to check the validity of any conventional shrink rule on this particular type of dimension. Since the corresponding pattern configurations would also be slots, and repair of oversize slots in the pattern might prove a difficult if not impossible task, a conservative approach was necessary.

The slots in the pattern were made to a size certain to produce undersize slots in the castings. Twenty-five castings of each piece number were made using the shell-pattern equipment and production shell-molding machines and procedures. Each of the slots was measured and mean dimensions and standard deviations were calculated. These values together with the corresponding pattern dimensions and $\overline{X}$ & R control limits for sub-groups of five are given in Table 2.

Examination of the values in Table 2 shows the mean dimension of the castings to range from 0.0035 to 0.0058 in. less than the corresponding pattern dimensions, and these values to be approximately 0.025 in. less than the ideal mean dimension of 0.510 in. The results did show, however, a maximum standard deviation of only 0.0021 in., indicating that the 3 sigma limit of ± 0.0063 in. were well within the specification of ± 0.010 in., and, therefore, once the proper pattern dimensions were established, no difficulty should be encountered in meeting print specifications.

The pattern slots were increased from their initial 0.478-0.492 in. size to 0.515-0.516 in., and twenty-five representative castings of each piece number were again measured, and subjected to statistical analysis. The results of this analysis, together with appropriate corresponding pattern dimensions are in Table 3.

TABLE 3 – DIFFERENTIAL CASE "A" FINAL TEST

Piece No. 1

Slot No.	Pattern Dimension	Mean Dimension $\overline{X}$	Standard Deviation	Average Range	For Sub-Group of 5 $UCL_{\overline{X}}$	$LCL_{\overline{X}}$	UCL_R	LCL_R
1	0.516	0.5125	0.0015	0.0036	0.5148	0.5104	0.0077	0
2	0.515	0.5114	0.0015	0.0056	0.5146	0.5082	0.0118	0
3	0.516	0.5128	0.0010	0.0023	0.5141	0.5115	0.0049	0
4	0.515	0.5117	0.0010	0.0022	0.5130	0.5106	0.0046	0

Piece No. 2

Slot No.	Pattern Dimension	Mean Dimension $\overline{X}$	Standard Deviation	Average Range	For Sub-Group of 5 $UCL_{\overline{X}}$	$LCL_{\overline{X}}$	UCL_R	LCL_R
1	0.516	0.5114	0.0010	0.0023	0.5127	0.5101	0.0048	0
2	0.516	0.5109	0.0017	0.0039	0.5132	0.5086	0.0082	0
3	0.515	0.5089	0.0025	0.0058	0.5122	0.5056	0.0122	0
4	0.515	0.5091	0.0020	0.0046	0.5117	0.5065	0.0097	0

It will be noted that with one sampling and a single correction, it has been possible to produce castings with a mean dimension within 0.003 in. of the ideal mean dimension. Further, recheck of the standard deviation shows a maximum of 0.0025 in., corresponding to a 3-sigma limit of ± 0.0075 in., well within the requirements. Presuming normal distribution, the extreme dimensional limits which may be expected of 99.7 per cent of castings produced with these pattern dimensions are 0.5014 in. and 0.5170 in., both values well within customer limits of 0.500 in. and 0.520 in.

The control limits calculated in the final test of this differential case, and given in Table 3, become usable values for quality control sampling procedures for the finished castings before shipment. Pattern dimensions are subject to periodic check for either possible wear or pattern build-up.

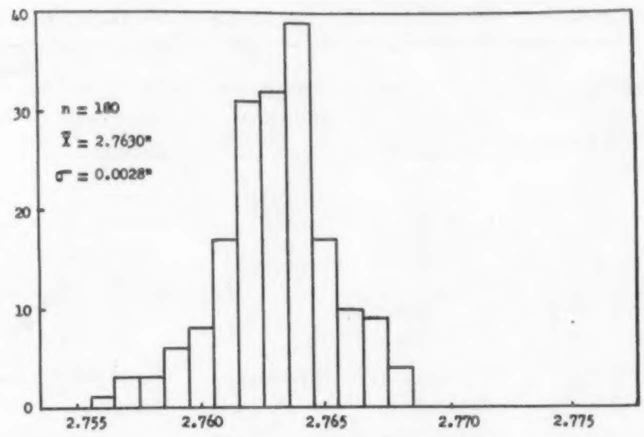
Similar procedure to that described above was used to establish the slot sizes of the entire series of split differential cases. The shrinkage, pattern to casting, in general approximated the 0.010 in./in. shrink rule, the values being within the range of 0.003 in. to 0.006 in. on the nominal ½-in. dimension. There was one notable exception to this general statement. On one of the castings, of basically the same design as all the rest, there was a radical departure from the expected shrink (see Table 4 for numerical values). Note that on slot Nos. 2 and 4 there was a somewhat lower than average shrinkage, pattern to casting, and that on slot No. 3 there was a very slight shrinkage, and on slot No. 1 there was an actual increase in the average width. No explanation is offered for this unexpected result, except to state that minor difference in design must have produced a stress pattern in the casting during and immediately after solidification which altered the normal shrinkage pattern. This result, however, did serve as a caution against future indiscriminate application of any standard shrink rule for castings of reasonably complex shape, and on which castings there are close dimensional tolerances.

PROCESS CAPABILITY OF SHELL CORE BLOWING

Information on the dimensional control capabilities of two types of blown shell cores was desired. The first of these, referred to subsequently as shell core "A", was approximately 19 in. long and 2 3/4 in. maximum diameter, and the second, referred to as shell core "B", was approximately 12 in. long and 3 1/4 in. maximum diameter. Each of these cores was made in a single opening of a two-opening box, the other opening in each case being of slightly different dimensions to produce the same finished casting size in another material. Only the results of the one opening are reported here.

TABLE 4 – SPLIT GEAR CASE "B"

Slot No.	Pattern Dimension	Mean Dimension, $\overline{X}$	Standard Deviation	Shrink, Pattern to Casting
Piece No. 1				
1	0.498	0.4985	0.0019	−0.0005
2	0.498	0.4951	0.0027	+0.0029
3	0.499	0.4984	0.0019	+0.0006
4	0.500	0.4969	0.0029	+0.0031



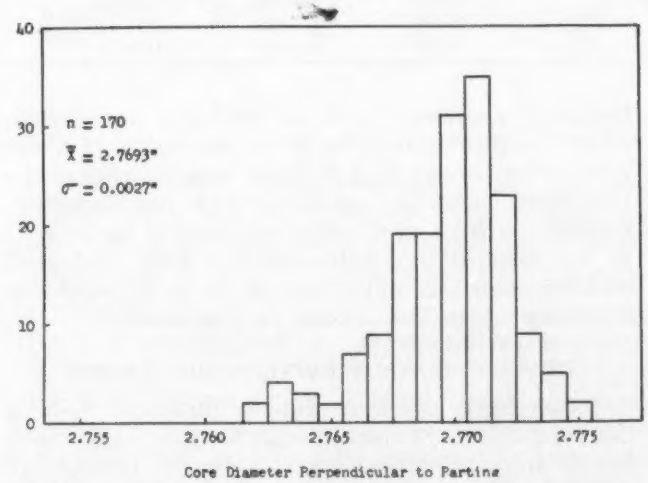


Fig. 3 – Histograms of frequency distribution of diameters of shell cores parallel to and perpendicular to the parting—shell core "A".

A histogram of the results obtained on the initial tests of shell core "A" is shown in Fig. 3. Note that although the standard deviations for measurements parallel to and perpendicular to the core box parting are nearly identical (0.0028 in. and 0.0027 in., respectively), the mean dimensions differed by approximately 0.006 in., the dimension perpendicular to the parting being the larger. With this approach to the problem, it has not only been possible to ascertain dimension accuracy to be expected under these initial conditions, but values for corrections to the core box to obtain minimum eccentricity have been definitely established.

In the last case to be considered, that of shell core "B", greater detail of procedure and results are given for the benefit of those interested, and to indicate the manners in which such results may be summarized and displayed.

In this instance, with larger cores than those described in the immediately preceding discussion, somewhat more elaborate equipment, in the form of a rigid carriage for handling the core box in and out of the core blower, was employed. A summary of the measurement data is given in Table 5, and displayed in graphical form in the histograms of Fig. 4.

It may be seen from both the data and the histo-

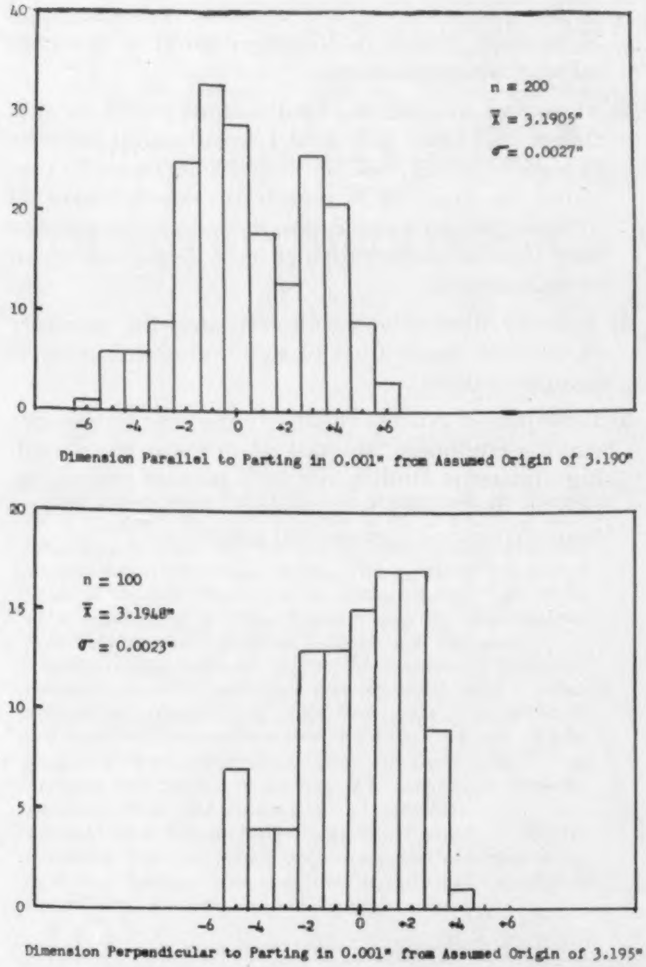


Fig. 4 – Histograms of frequency distribution of diameters of shell cores parallel to and perpendicular to the parting–shell core "B".

grams that, as in the case of shell core "A", the mean dimension is greater perpendicular to the core box parting than parallel to it. An added bit of information is more readily seen on the histograms. Whereas the dimensions perpendicular to the parting follow an approximately normal distribution curve, those parallel to the parting show two rather than a

TABLE 5 – SHELL CORE DIMENSIONS – SHELL CORE "B"

	Frequency	
Dimension	Parallel to Parting	Perpendicular to Parting
3.184	1	
85	6	
86	6	
87	9	
88	25	
89	33	
90	29	7
91	18	4
92	13	4
93	26	13
94	22	13
95	9	15
96	3	17
97		17
98		9
99		1
Total	200	100

TABLE 6 – COMPUTATION OF AVERAGE AND STANDARD DEVIATION OF FREQUENCY DISTRIBUTION OF DIMENSIONS PARALLEL TO PARTING OF 100 SHELL CORES

		Shell Core "B"		
x	f	d	fd	fd²
3.184	1	6	6	36
85	6	5	30	150
86	6	4	24	96
87	9	3	27	81
88	25	2	50	100
89	33	1	33	33
90	29	0	0	0
91	18	−1	−18	18
92	13	−2	−26	52
93	26	−3	−78	234
94	22	−4	−88	352
95	9	−5	−45	225
96	3	−6	−18	108
Total	200		−103	1485

$\overline{X}$ (from assumed origin of 3.190) $= \frac{\Sigma fd}{n} = \frac{-103}{200} = -0.515$

$\overline{X} = 3.190 + 0.0005 = 3.1905$ in

$$\sigma = \sqrt{\frac{\Sigma fd^2}{n} - \left(\frac{\Sigma fd}{n}\right)^2} =$$

$$\sqrt{\frac{1485}{2} - (.5)^2} = \sqrt{7.425 - .250} = \sqrt{7.175} = 2.7$$

σ (in original units) $= 0.0027$ in.

TABLE 7 – COMPUTATION OF AVERAGE AND STANDARD DEVIATION OF FREQUENCY DISTRIBUTION OF DIMENSIONS PERPENDICULAR TO PARTING OF 100 SHELL CORES

		Shell Core "B"		
x	f	d	fd	fd²
3.190	7	5	35	175
91	4	4	16	64
92	4	3	12	36
93	13	2	26	52
94	13	1	13	13
95	15	0	0	0
96	17	−1	−17	17
97	17	−2	−34	68
98	9	−3	−27	81
99	1	−4	−4	16
Total	100		20	522

$\overline{X}$ (from assumed origin of 3.195) $= \frac{\Sigma fd}{n} = \frac{20}{100} = 0.2$

$\overline{X} = 3.195 - 0.0002 = 3.1948$ in.

$$\sigma = \sqrt{\frac{\Sigma fd^2}{n} - \left(\frac{\Sigma fd}{n}\right)^2} =$$

$$\sqrt{\frac{522}{100} - (.2)^2} = \sqrt{5.22 - .04} = \sqrt{5.18} = 2.3$$

σ (in original units) $= 0.0023$ in.

single peak series of values. It should be explained at this point that two readings of diameter were taken approximately parallel to the parting, one on each side and immediately adjacent to the actual parting.

The twin peak effect is due to a slight mismatch caused by slightly different diameters of the core box halves at the parting. A recheck of the core box at room temperature failed to disclose any significant difference. The difficulty was then assignable to slightly different heating of the core box halves. No actual correction was made for this condition, since the error introduced from this source appeared to be of the magnitude of approximately 0.002 in., and then extant dimensional requirements did not warrant

the expense. The measurably better standard deviation obtained with the larger core (average sigma 0.0025 in. as compared to 0.0027 in. for shell core "A") is attributed to the greater rigidity of the equipment and the mechanization of core box opening employed with shell core "B".

CONCLUSIONS

1) Process capability in the production of an automatic transmission part in pearlitic malleable iron was readily ascertainable by a statistical approach. Standard deviations proved to be 0.0020 in./in. on approximately 3-in. diameters and 0.0013 in./in. on approximately 6-in. diameters within a mold half, and standard deviation across a mold parting was 0.0050 in./in. on an approximately 2-in. dimension.
2) Advantages of the shell process for the production of the transmission part were closer dimensional tolerances which 1) reduce metal removal, 2) increase ease of static and dynamic balancing, and 3) provide greater uniformity desired in automated machining operations.
3) Statistical analysis of initial pattern tryout on split differential cases indicated 1) relationship between process capability and customer tolerances, 2) provided an exacting approach to establishment of critical pattern dimensions in a single corrective step without danger of high cost of pattern repair or replacement.
4) A single illustrative result indicated the necessity of cautious application of standard shrink rules to complex castings.
5) Examples of process capability studies of shell core making equipment showed, as in the cases of casting dimension studies, not only present process capability but indicated numerical values for corrections to improve dimensional accuracy.

AMERICAN FOUNDRYMEN'S SOCIETY – PREPRINT NO. 58-47
This paper has been approved for presentation at the 62nd Annual Meeting of the American Foundrymen's Society, to be held in Cleveland, Ohio, May 19-23, 1958. The Society reserves all rights for publication either prior to or subsequent to presentation, and is not responsible for statements or opinions advanced herein.
WRITTEN DISCUSSION IS SOLICITED

INDUCTION MELTING IN A MAGNESIUM SAND FOUNDRY

By

J. G. House* and M. E. Brooks*

ABSTRACT

This paper describes a limited amount of work done in a magnesium sand foundry with a line-frequency induction furnace for melting primary magnesium and various forms of foundry scrap. The operating characteristics of the induction furnace are compared with those of a gas-fired tilter type furnace and the maintenance problems of the induction furnace are discussed.

Interest was aroused in the line-frequency induction furnace when its operation was observed at a German automobile plant. This plant has several units which are used as pre-melters for holding furnaces, which supply molten magnesium alloy to their gravity and pressure die casting machines. The operation gave indications that this furnace is an efficient, clean, economical tool for melting magnesium alloys. With the extensive German plant experience to recommend it, a similar furnace was installed in the sand foundry of the authors' company.

GENERAL DESCRIPTION OF INDUCTION FURNACE

The channelless line-frequency induction furnace is rated at 450 KW and uses a cast steel crucible of about 1300 lb molten magnesium alloy capacity. Inside dimensions are approximately 23½-in diameter by 60-in deep, giving about 14 cu ft of volume. The furnace has three independent coils, each controlled by its own thermocouple which butts against the crucible in the area heated by the coil. The coils are hollow and have cooling water flowing through them during operation. The crucible is of cast steel about 3 in. thick and acts as an inefficient secondary coil. This arrangement generates about 85 per cent of the heat in the crucible wall, and 15 per cent in the melt itself. This low-frequency current (60 cycle) imparts considerable stirring action to the melt. This stirring contributes to fast melting by washing molten metal past the hot crucible wall and over the solid metal charge. This stirring also homogenizes the melt.

The furnace is mounted upon hydraulic cylinders so that the whole assembly may be tilted through 90 degrees for cleaning, or any intermediate angle for pouring any portion of the melt. The furnace occupies a floor space of about 60 x 76 in. and stands 70 in. high. It is mounted for convenience of operation in a pit 17 in. deep.

The operating controls for the furnace consist of a small room of capacitors and switch gear, a console

Fig. 1 – Line-frequency induction furnace.

for controlling and monitoring the electrical part of the furnace, and a console for controlling the hydraulic tilting mechanism. The capacitors and switch gear are enclosed to protect them from flux and flux fumes, and the room may be any reasonable distance from the furnace. Both of the control panels should be located in the immediate area of the furnace.

The furnace has been used in the company's sand foundry to melt metal for use in a holding furnace, and for regular crucible practice.

INDUCTION FURNACE OPERATIONS

All of the different forms of melting stock that are used in normal magnesium foundry practice have been melted in the induction furnace. The operations with clean scrap and primary magnesium were very satisfactory, although primary magnesium had a tendency to bridge. This bridging is not serious if the operator expends a reasonable effort in loading and maintaining the flow of solid metal down into the liquid pool. Scrap with a large amount of screens in it presented a problem only in that the melting

*Chief Research & Development Engr., Dow Chemical Co., Bay City, Mich.

**Foundry Engineer, Magnesium Dept., Dow Chemical Co., Bay City, Mich.

Fig. 2 — Gas-fired tilter type furnace.

operation had to be interrupted at more frequent intervals for sludging. The furnace can be tilted at such an angle as to allow the screens and sludge to be pulled slightly uphill during sludging, which gives an excellent metal-waste separation.

A limited amount of die cast scrap was satisfactorily melted in the furnace. The smoke and fumes from the die lubricant on the scrap presented a problem not otherwise encountered, but which could be remedied with extra ventilation. Also, the charred lubricant and flux built up a coating on the sidewalls that had to be scraped down after each melt.

Chips from machine trimming operations were melted in the furnace but, due to their buoyancy, even with its violent stirring action the furnace could not wet them at a reasonable rate. This gave a high melting loss.

Alloying of aluminum and zinc was easily accomplished by putting a metal stool in the bottom of the crucible. The legs of this stool were long enough to keep the seat out of the sludge. The seat diameter was so nearly that of the crucible that alloying materials could not escape down the side and damage the crucible bottom.

When starting a melt to make new alloy, the proper amount of aluminum and zinc was added to the molten heel and then the main charge of primary magnesium was added. When the melt reached 1300 F, the charge was homogeneous in composition.

Manganese was added as $MnCl_2$ (Dow No. 250 flux), aluminum-manganese hardener (95% Al-5% Mn), and as M1A alloy (98.5% Mg-1.5% Mn). All were satisfactory within limits, but the manganese in the Dow No. 250 flux and in the Al-Mn hardener do not go into solution well unless the melt temperature is somewhat above 1300 F, which precludes pouring below that temperature. M1A alloy can be charged with either scrap or primary magnesium, and the manganese goes into the alloy with excellent efficiency.

Samples, if taken at melt temperatures of 1300 F or above, give the true composition of the melt. Samples taken below this temperature usually show a lower level of aluminum and zinc than the melt actually contains. This lack of homogeneity in melts sampled below 1300 F is probably due to insufficient time for complete mixing and diffusion of the alloying elements into the upper part of the melt.

Starting an induction furnace run may be accomplished with a solid charge frozen in the furnace, with solid charge materials, or by charging a liquid heel. If liquid metal and handling facilities are available, the latter method is the most advantageous with respect to heat cost and time.

If clean scrap or primary magnesium is being melted, the furnace does not require sludging until after ten or 12 melts have been processed. Melting scrap which contains screens or dirty scrap requiring larger amounts of flux, will necessitate more frequent sludging, decreasing the period of continuous operation.

COMPARISON OF INDUCTION AND GAS-FIRED TILTING FURNACES

Molten metal produced in the induction furnace was of a quality comparable to that produced in a gas-fired tilter. No specific tests were made but no evidence of oxides or flux inclusions was apparent.

Grain refining by carbon inoculation or superheating was not tried in the induction furnace. Carbon inoculation should present no problems. Superheating would be expensive as the temperature differential between the crucible wall and the metal becomes very small at temperatures of 1550 F and above, and thus the heating rate is very slow. It is possible, however, to heat the melt in excess of 1600 F.

Degassing with chlorine gas was done in the induction furnace and was very effective. The only drawback here was that the time spent for gas removal was lost for molten metal production.

Operating characteristics such as melting rate, meltdown metal loss, flux consumption, fuel, and labor, of the induction furnace were compared with those of a 2000-lb capacity gas-fired tilting furnace. The comparison is not quite equitable as the gas-fired tilting furnace was used on a batch basis, while the induction furnace was used in a semi-continuous operation.

Gas-fired furnace data were obtained by making one melt each with primary magnesium plus alloying materials, clean scrap, and screeny scrap. A one-shift run was made with each of these materials in the induction furnace, plus a run of three melts of machine trim chips, and a five-melt run of die cast scrap. AZ63A was used in all the runs except the die cast scrap, which was AZ91A.

Melting Rates

Melting rates, of course, depend upon many factors

TABLE 1 – MELTDOWN METAL LOSS AND FLUX CONSUMPTION

	Primary Mg + Alloy		Clean Scrap		Screeny Scrap*	
	Flux Used, %	Meltdown Metal Loss, %	Flux Used, %	Meltdown Metal Loss, %	Flux Used, %	Meltdown Metal Loss, %
Induction Furnace	1.0	0.5	0.65	0.14	0.9	1.2
Gas-fired Tilting Furnace	1.5	1.1	0.8	0.6	2.5	3.7

*The weight of scrap melted was corrected for the weight of screens it contained.

including the type of material being charged and the pouring temperature. Technical personnel obtained induction furnace melting rates as high as 1850 lb/hr for clean scrap, and 1600 lb/hr for primary magnesium plus alloying materials, both poured at 1300 F.

When scrap was melted, pours were of 850 lb, and when primary magnesium plus alloy was being melted, pours were of 700 lb. As the furnace holds 1300 lb, this means that a considerable heel is left, but when pounds poured versus melting rate was plotted for a large number of melts, these amounts of metal poured each cycle of operation gave the highest melting rates. To measure these amounts, a calibrated quadrant was welded onto the pivot point of the furnace. The amounts of these pours correspond to tilting through 65 degrees for scrap and 60 degrees for primary magnesium plus alloy.

Melting rates of from 750 to 1500 lb/hr with an average of 1230 lb/hr were obtained over a week's production run of two shifts a day. During this period the cycle of operations was such that a pour was made about every half hour. The charges of metal melted during this production run were about equally divided between new metal to be alloyed and batches of clean scrap. The time included all charging, sludging, time lost at the beginning and end of each day's run, etc. All metal was transferred at 1300 F.

In comparison, the gas-fired tilting furnace, using a batch cycle, gave about 550 lb/hr melted and poured at 1300 F. It is estimated, however, that two gas-fired furnaces using a semi-continuous melting cycle similar to that used in the induction furnace operation would give as many pounds melted per hour as one induction furnace.

Metal Loss

Meltdown metal loss varies with the material being melted. Screens or the use of extra amounts of flux tend to entrap more metal in the sludge. The losses recorded here are those incurred while transforming solid metal into molten metal (Table 1). This loss is only a small part of the total loss generated during the complete melting, processing, and casting cycle.

The data given in this table are based on the processing of about 5500 lb. of metal through the induction furnace and about 2000 lb of metal through the gas-fired tilting furnace.

In addition to the melting of the types of material given in Table 1, about 3000 lb of die cast scrap and about 2000 lb of machine chips were melted in the induction furnace with metal losses of 8.1 and 7.7 per cent, respectively. The flux consumption was 5.1 per cent on the die cast scrap and 6.5 per cent on the machine chips.

The lower meltdown metal loss found on the induction furnace runs is probably due to two factors. First, the induction furnace melts metal much faster than the gas-fired tilter, and therefore there is less time for burning to occur during meltdown. Second, there is a capacity-surface area ratio of about 3 lb of metal per sq in. of melt surface area in the induction furnace, while in the gas-fired tilter furnace this ratio is about two to one.

The accuracy of any metal loss determination depends upon the exactness of the weighing done in conducting it. Weighings for these meltdown metal losses were made on a 2000-lb capacity platform scale. To eliminate "zero" error, all weighings were made by difference. In the case of solid items such as primary magnesium, scrap, aluminum, or zinc, a steel rack was left on the scale while weighing to give an "empty" weight. Molten metal was weighed by weighing a crucible plus shank before and after filling.

Flux Consumption

During the meltdown, flux has to be added repeatedly to control burning in both the gas-fired tilter and in the induction furnaces. Once meltdown is complete, one covering will suffice. This will not be true for the induction furnace unless there is a sufficient height of metal over the top coil so that the stirring action does not break the surface flux film. This can be accomplished by welding a 4-in. collar around the top of the crucible so that more depth can be obtained above the top coil. Dow No. 230 flux was used for all the runs with the exception of the die cast scrap run, when Dow No. 234 was used.

Fuel Consumption

Fuel consumption figures were taken as the average of eight shifts of 8 hr each for the induction furnace and for one melt on the gas-fired tilter. On this basis fuel requirements were 0.265 KWH/lb melted in the induction furnace, and 2.5 cu ft of natural gas (1000 BTU/cu ft) per pound melted in the gas-fired tilter furnace. The cost of warming the induction furnace crucible up is a material item and the more melts that can be spread over one warm-up, the lower the KWH per pound. For example, over one run covering two shifts (16 hr) of continuous operation, during which just about ideal conditions existed, a figure of 0.202 KWH/lb melted was obtained.

Labor

One man could run two adjacent induction furnaces or four adjacent gas-fired tilters. This would give the gas-fired tilters and induction furnaces of the sizes used in this work about the same labor cost per pound of metal melted.

MAINTENANCE OF THE INDUCTION FURNACE

Other than routine electrical and hydraulic maintenance, the crucible is the only part of the furnace needing regular repair. Although it is not exposed to a flow of air, it tends to oxidize, and the scale formed must be removed periodically from the furnace pit before it can build up enough to become a safety hazard or react with the crucible pit lining. When the crucible is sandblasted and aluminum sprayed prior to installation, it will run about 120 melts with no appreciable scaling.

While operating, the crucible is exposed to a magnetic field of considerable intensity. The magnetic force acting on the crucible while it is in a semi-plastic condition during the melting cycle causes the walls to bulge inward adjacent to the heating coils and outward between the coils. The inward bulging is of no consequence concerning maintenance, but the outward bulging must be considered. In time the bulges would contact the crucible pit lining, which would be torn out upon crucible removal.

The new cast steel crucibles are 28-in. in diameter and the crucible pit is 30 in. inside diameter. Rate of crucible growth is nearly linear, so it can be predicted when they will be about 29.5-in. diameter at the bulge. When this occurs, the crucible is machined back to its original diameter.

A good crucible will last at least 1000 melts and may have to be machined one or two times during that span.

Machining, which reduces the crucible wall thickness, and bulging, which increases the air gap between the coil and the crucible, decrease the melting rate. The uneven inside of a distorted crucible also decreases the melting rate as it is much more prone to cause bridging of the charge than is a new smooth crucible. A crucible with 500 melts on it may have its melting rate reduced by 3 per cent for scrap and 25 per cent for primary magnesium (42-lb pigs). The greater loss in melting rate for the primary magnesium is due to its greater propensity to bridge. The combined effect of less wall thickness, greater air gap, and more bridging may make it economical to discard a crucible before it becomes unsafe for use.

During periods of high humidity, the coils tend to sweat due to their being cool, and to pick up moisture because of the flux dust on them. If the furnace is started when they are wet, they may arc between themselves and burn a hole that will cause a water leak. Accumulation of moisture can be prevented by opening the back of the furnace and directing a battery of heat lamps on the coils during shutdowns.

The work with this low-frequency induction furnace shows that it is capable of melting magnesium alloy in the sand foundry under production conditions and when operated by production personnel. Based on somewhat limited experience, it would appear that the operating characteristics of the induction furnace compare favorably with those of conventional gas- or oil-fired melting units. The final decision as to whether the induction furnace or the gas- or oil-tilter furnace is the more desirable melting equipment will depend upon local considerations, including the relative costs of equipment and installation, fuel and power costs, and the molten metal requirements of the foundry.

AMERICAN FOUNDRYMEN'S SOCIETY – PREPRINT NO. 58-19
This paper has been approved for presentation at the 62nd Annual Meeting of the American Foundrymen's Society, to be held in Cleveland, Ohio, May 19-23, 1958.
WRITTEN DISCUSSION IS SOLICITED

INVESTIGATION OF THE HARDENING OF SODIUM SILICATE BONDED SAND

By

Carl E. Wulff

This investigation was undertaken to better understand the hardening mechanism of CO_2-bonded sand. Very little has been written of the manner and methods by which sodium-silicate-bonded sand is hardened. An understanding of the fundamentals that are involved in this bonding process certainly will aid in the solving of practical foundry problems.

The hardening of sodium-silicate-bonded sand falls into three categories:

1) Carbon dioxide hardening
2) H_2O evaporation hardening
3) Thermal hardening

Each of these methods was investigated, and form the basis for this paper. All tests were performed with the following materials unless otherwise stated:

Sand: Silica sand, washed and dried screen analysis

U.S. Std. Sieve No.	% Retained
20	...
30	1.8
40	17.2
50	30.7
70	27.2
100	15.5
140	5.9
200	1.3
270	.2
Pan	...
AFS G.F.N.	50.5

Binder: Commercial sodium silicate
Ratio $Na_2O:SiO_2 = 1:2.4$
Solids – 46.9%
Viscosity 17 poises
Baume 52°

Gas: Proprietary carbon dioxide

The above binder was used as it is the basis for the bulk of the proprietory binders now on the market. The effects of additives found in most commercial binders are eliminated in that the binder is 100 per cent sodium silicate. The sand was dried before using to avoid the influence of moisture on the bonding action. Mixing was accomplished in a standard 18 in. dia. laboratory muller. The muller was sealed to avoid any presetting of the sand during mixing.[1]

Standard tensile samples were produced with three rams of the standard sand rammer. Gassing was accomplished with a gas pressure of 10 psi, unless otherwise stated; the gas entering the top of the core while in the corebox and passing out through a 40-mesh screen at the bottom.

The standard tensile test specimen cores were used in this investigation and as they are relatively small cores (105 gm) the results should be interpreted with this in mind.

CO_2 Hardening

In order to show the hardening due to CO_2 reaction, the sodium silicate sand was gassed with wet CO_2 produced by bubbling the gas through water. In Fig. 1, the specimen gassed with wet CO_2 gained strength up to one min and then lost strength; half the maximum strength being produced in the first 10 sec of gassing. In gassing with dry CO_2, a curve similar to the wet CO_2 curve resulted but with a slow rise and fall. In both cases, slightly over 40 psi maximum strength was developed for 3 per cent binder.

Figure 2 shows the effect of gassing time versus tensile strength for various binder percentages; additional binder requires a longer gassing time to reach peak strength. Gas pressure was reduced to 3 psi to obtain a slower rate of flow; thus allowing the CO_2

*Instructor, Dept. of Mining & Metallurgy, University of Wisconsin, Madison, Wisc.

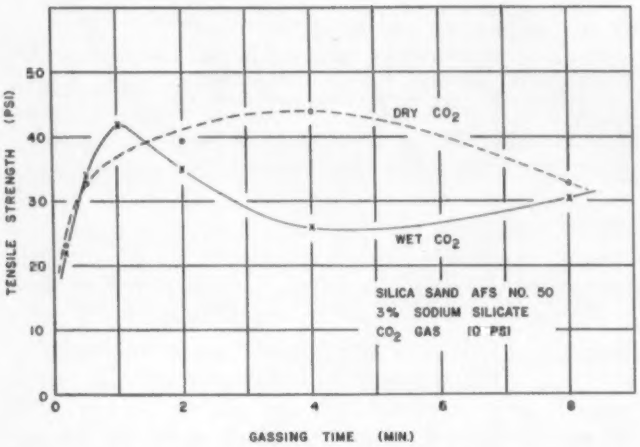


Fig. 1 – The effect of gassing time on tensile strength for wet and dry CO_2 gas.

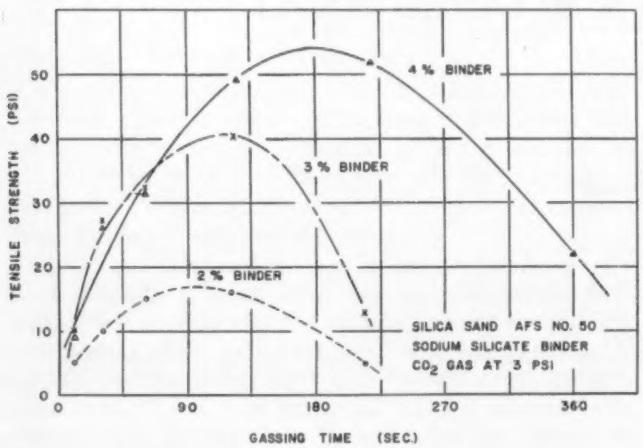


Fig. 2 – Gassing time versus tensile strength for three different binder percentages.

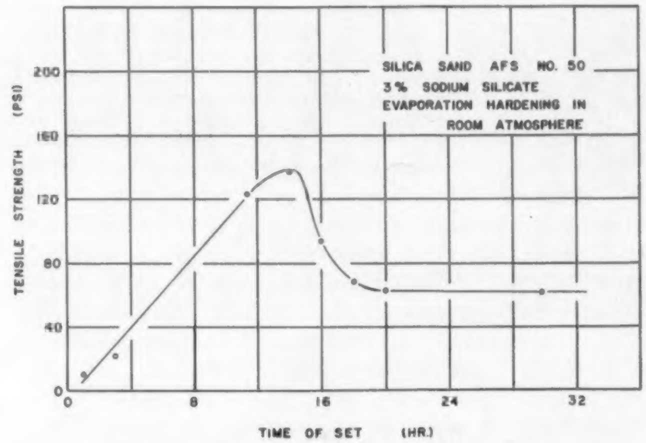


Fig. 3 – Evaporation hardening as shown by tensile strength for various hardening periods.

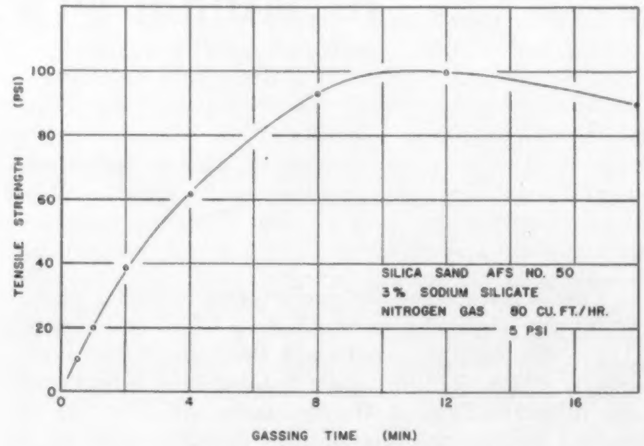


Fig. 4 – The variation of tensile strength with nitrogen gassing time.

gas to have ample time to react with the sodium silicate. This lower rate of flow would tend to minimize the evaporation of H_2O of the binder.

H_2O Evaporation Hardening

The tensile strength developed by the sample in room atmosphere is shown in Fig. 3. Room temperature was 70 to 75 F and relative humidity was 62 to 70 per cent. The tensile strength increases rapidly, reaching a maximum in 14 hr, and then rapidly decreases and levels off at approximately half the maximum strength. Referring to Fig. 1, it appears that the maximum evaporation hardening strength is three times the maximum CO_2 hardening strength.

Hardening by moisture evaporation can also be demonstrated by gassing with a gas other than CO_2. Figure 4 shows the result of gassing with nitrogen and testing immediately. The strength rises rapidly, reaches a maximum, and then falls slightly.

In order to determine if the moisture in the air had any effect on the hardening; samples were gassed with CO_2 for 20 sec and then placed in a dessicator and in room atmosphere. Figure 5 shows the curve for each condition. Samples gassed with CO_2 and then placed in low humidity atmosphere reach a slightly higher strength but fall to a somewhat lower strength.

The effect of gassing with CO_2 on the evaporation hardening is shown in Fig. 6. Gassing times of 10 sec and 40 sec were used and, except for the initial strength immediately after gassing, the gassing time does not seem to affect the evaporation hardening strength to any great extent. The evaporation hardening strength attains a higher value without gassing than with gassing, but falls to a lower value. Gassing with wet or dry CO_2 (Fig. 7) does not seem to affect the evaporation hardening strength, but the wet CO_2 specimen required a longer set time.

Characteristic curves of evaporation hardening for various binder percentages are shown on Fig. 8. The tensile strength rises to a maximum in 16 to 24 hr, drops off approximately 25 per cent and then levels off.

Thermal Hardening

Sodium silicate bonded sand can be hardened by heating as shown on Fig. 9. As the specimen hardens, the strength increases until it is hard throughout. After 125 min the tensile strength was 185 psi, and after 4 days the strength was 187 psi. Thus it appears that additional heating time does not increase the

strength. Specimens were broken immediately after removing from the oven.

The strength of thermal hardening depends upon the temperature to which the specimen is heated. Figure 10 shows how the tensile strength varies with the hardening temperature; the maximum strength being developed at approximately 300 F, further increases in temperature producing lower strengths. This curve agrees very well with a typical curve, Fig. 11, which is characteristic of the strength variation with temperature.[2] The thermal hardening retains most of its high strength during a period of set, as shown by Fig. 12.

The effect of gassing with CO_2 prior to the thermal hardening is shown by Fig. 13. As the time of gassing is increased, the strength attained by the thermal set is reduced.

Chemical Hardening

To check the possibility that there may be a chemical reaction between the binder and the sand which may aid the hardening of the specimen, the following test was performed. Specimen cores in an unhardened state were placed in a 100 per cent humidity atmosphere. After a period of several weeks they still retained their soft condition and showed no tendency to harden. When placed in an oven at 220 F, they hardened to the same strength as the specimens placed in the oven immediately.

Core Deterioration

The loss of strength of a sodium silicate bonded core is an important practical matter and so tests were made to determine the cause.

The effect of moisture was demonstrated by placing cores hardened by CO_2 hardening and thermal hardening in 100 per cent humidity. Both cores became soft and entirely without strength during a period of several days. An attempt was made to reharden the CO_2 set core with CO_2 gas, but practically no strength was attained. The thermal set core was placed in an oven and reached one-third of its former high strength (260 psi). In another test, cores hardened at 400 F were placed in 100 per cent humidity. When they became entirely soft (3 days), they were gassed with CO_2 and thermally hardened.

The results showed that a core which is hardened by thermal hardening and then softened in 100 per cent humidity can be rehardened to its original strength by thermal hardening. When this softened core is hardened by CO_2 gas its strength is just slightly less than if hardened with CO_2 immediately after

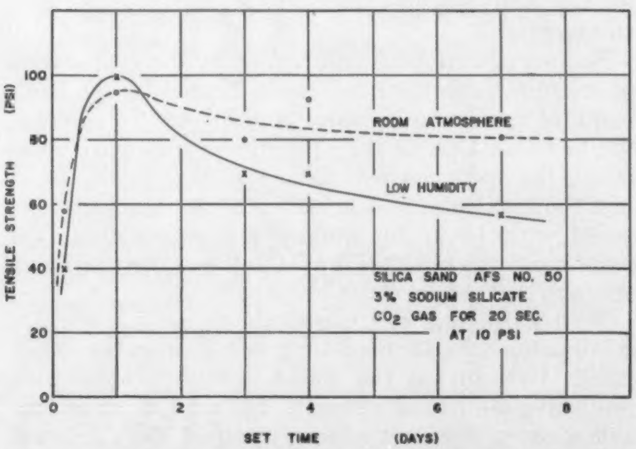


Fig. 5 – The effect of atmosphere as shown by the tensile strength for various set periods.

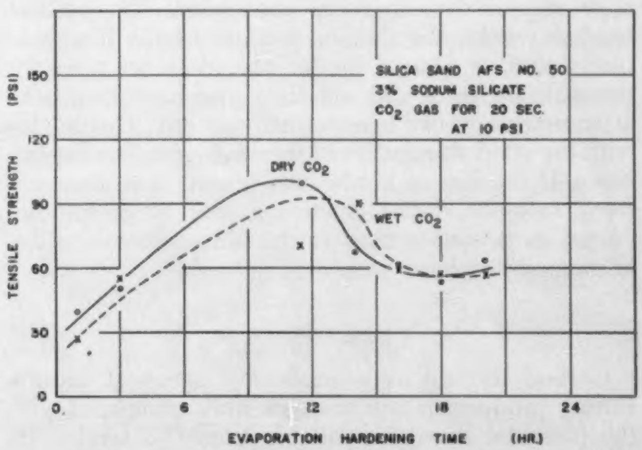


Fig. 7 – Evaporation hardening strengths after gassing with wet and dry CO_2 gas.

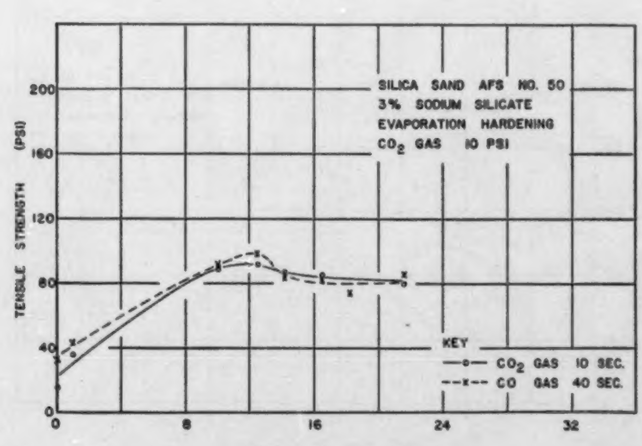


Fig. 6 – Effect of the time of CO_2 gassing upon evaporation hardening.

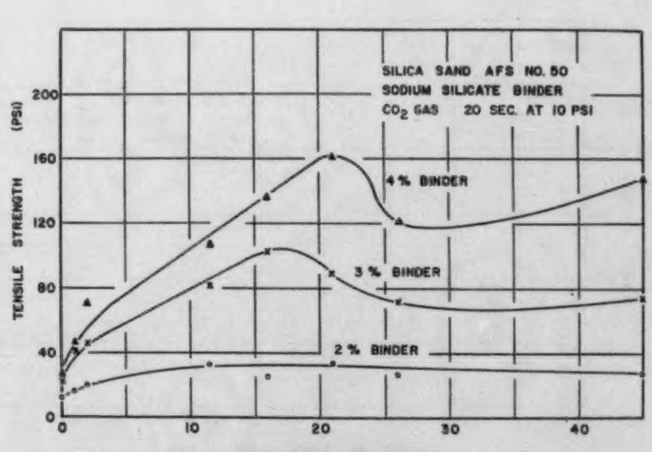


Fig. 8 – Evaporation hardening curves for various binder percentages.

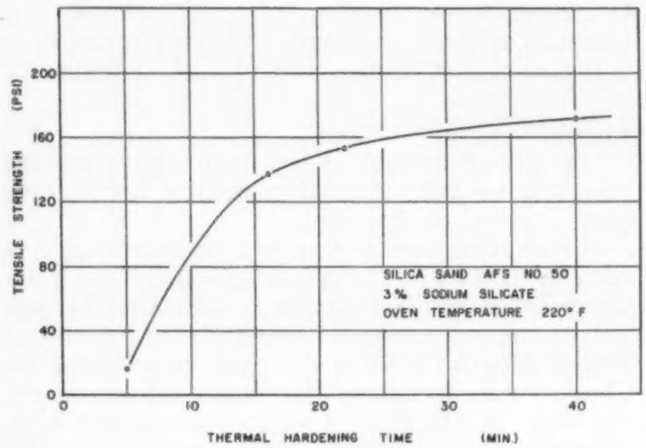


Fig. 9 — Effect of thermal hardening time upon tensile strength.

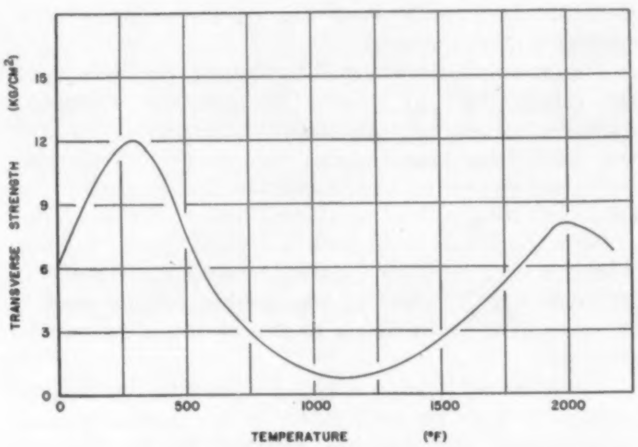


Fig. 11 — Typical curve of strength variation with temperature.

mixing. A core fused at 2000 F lost almost half its strength but remained hard (scratch hardness 85). Even when placed in water for a week, this core retained its hardness.

It was suggested by Richard Heine that a thin film of sodium silicate placed on a smooth hard surface such as a glass might give some indication of the nature of strength loss. The thin film of binder after several days in room atmosphere showed fine hairline cracks, the thinner portions of the film fracturing first. A film of binder placed in an oven for thermal hardening did not show the fracturing even after several weeks in room atmosphere. This agrees with the good storage life of thermally hardened specimens. If the film of binder was placed in a moisture-free atmosphere, the fracturing due to drying occurred even sooner than in the films allowed to dry in room atmosphere.

DISCUSSION

Carbon dioxide as a hardening agent of sodium silicate produces a low strength when compared with the potential strength available from this binder. Its chief merit lies in its ability to harden the sand mixture rapidly and produce half its maximum strength in 10 sec. Overgassing quickly results if CO_2 hardening is the only hardening mechanism acting.

The gassing time required to reach maximum strength varies with the percentage of binder in the sand. The more binder present the greater will be the strength if sufficient gassing is performed. This, of course, agrees with the concept of a film of sodium silicate surrounding the sand grains; within limits a thicker film requires more CO_2 and results in a stronger bond.

Sodium silicate sand will harden by the evaporation of moisture from the binder as indicated by the hardening of specimens in room atmosphere. To discount the fact that CO_2 in the atmosphere may have some effect, the specimen was gassed with nitrogen. In 12 min the maximum tensile strength was reached compared with 14 hr for atmosphere evaporation. The more rapid the moisture loss, the lower the maximum strength that can be attained.

Most hardening of sodium silicate sand cores is a combination of CO_2 hardening and evaporation hardening; CO_2 giving the initial set and evaporation producing additional strength. The amount of reasonable gassing does not appear to affect the maximum strength that a certain sand mix will reach. Thus, just enough gassing to make a core that can be han-

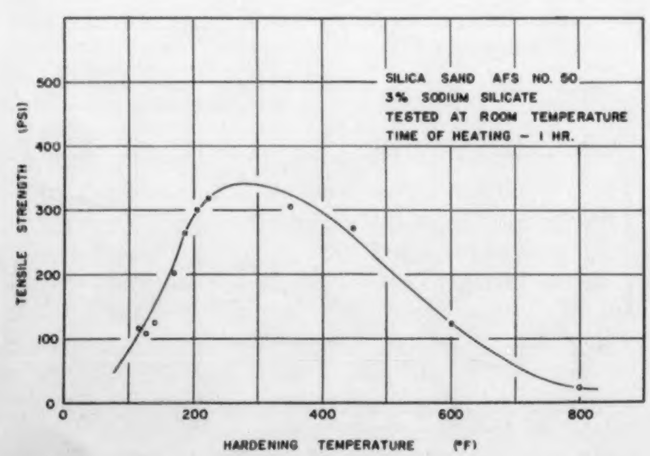


Fig. 10 — Effect of hardening temperature upon tensile strength.

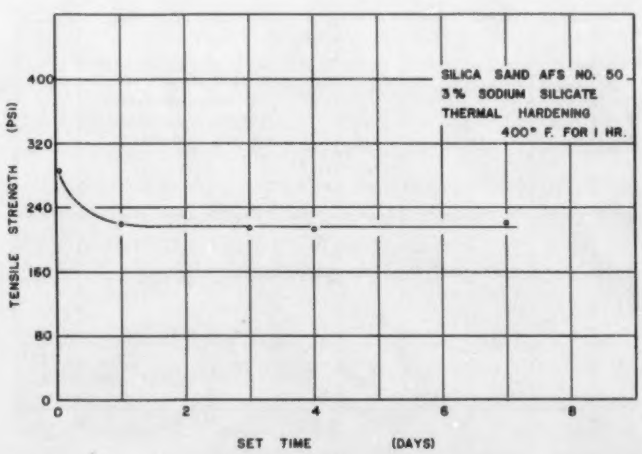


Fig. 12 — The variation of tensile strength with set time for thermally hardened specimens.

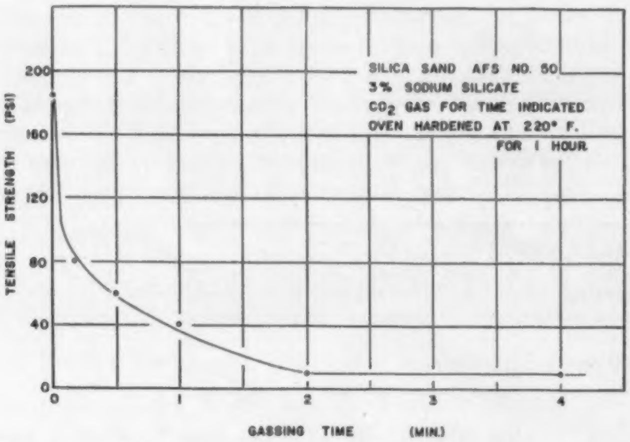


Fig. 13 – The effect of CO_2 gassing time on tensile strength for thermally hardened specimens.

dled and then hardening by evaporation appears to be best from an economic standpoint.

It is characteristic of the evaporation hardening and CO_2-evaporation hardening to rise to a maximum, decline, and then level off. The evaporation hardening without gassing reaches a higher maximum but also drops off a greater amount. The reason for the decline after reaching a maximum will be discussed later. The highest strength that can be obtained is by heating the specimen or thermal hardening. This type of hardening appears to be of a different nature from CO_2 and evaporation hardening for the following reasons:

1) Much higher strengths are obtained.
2) The high strengths are retained.
3) Thermal set is drastically reduced by prior CO_2 hardening.
4) Fracturing of the binder film does not seem to occur as readily as in evaporation hardening.

Thermal hardening is a way of obtaining high strengths with moderate binder percentages.

No hardening appears to develop unless CO_2, evaporation, or heat or combination of these are applied to the sand mixture.

The room temperature deterioration of cores apparently occurs by two mechanisms:

1 Fracturing of binder film, or
2) Softening of binder film.

The first is by cracking of binder due to the evaporation of moisture or prolonged gassing. Cores hardened by the thermal method do not readily deteriorate by this process. In CO_2-evaporation hardening this deterioration is evident in the decline from a maximum strength of the characteristic time-hardening curves. This type of deterioration is most noticeable in the weak edges and other friable parts which lose moisture rapidly.

The softening of the binder film is due to the pickup of moisture from the atmosphere. All three types of hardening are affected by this reversible process, but to the least extent in thermally hardened cores. The amount of moisture in the atmosphere will affect the rate of deterioration.

CONCLUSIONS

1) Hardening of sodium silicate bonded sand can be accomplished by three methods:
   a) CO_2 hardening
   b) H_2O evaporation hardening
   c) Thermal hardening
2) The CO_2 hardening and evaporation hardening, although achieved by different mechanisms, appear to be similar.
3) Thermal hardening is different from the CO_2-evaporation hardening, but in the lower temperature range of oven baking it is still a reversible process.
4) Long CO_2 gassing is of no advantage, and for economic reasons evaporation set is recommended.
5) Thermal hardening produces high strengths at moderate binder percentages.
6) Room temperature core deterioration can be of two types:
   a) Fracturing of binder (moisture loss)
   b) Softening of binder (moisture pickup)

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AMERICAN FOUNDRYMEN'S SOCIETY – PREPRINT NO. 58-62
This paper has been approved for presentation at the 62nd Annual Meeting of the American Foundrymen's Society, to be held in Cleveland, Ohio, May 19-23, 1958.
WRITTEN DISCUSSION IS SOLICITED

FUNDAMENTAL STUDIES ON EFFECTS OF SOLUTION TREATMENT, IRON CONTENT, AND CHILLING OF SAND CAST ALUMINUM-COPPER ALLOY

By

E. M. Passmore,* M. C. Flemings** and H. F. Taylor**

ABSTRACT

The related effects of solution treatment temperature, iron content, and chilling on the structure and properties of aluminum-copper alloys have been studied. Solution treatment temperatures and times greater than those normally employed have been found to result in substantial property improvement of aluminum-copper alloy sand castings. For example, mechanical properties of 42,000 psi tensile strength, 27,000 psi yield strength and 7 per cent elongation were obtained in an unchilled 4.5 per cent copper alloy test specimen which had been solution treated at normal commercial solution treating temperature (960 F). Mechanical properties were raised to 47,000 psi ultimate tensile strength, 27,000 psi yield strength and 13 per cent elongation by using a step heat treating schedule with final solution temperature at 1010 F. Specimens were aged at 310 F before testing. The improvement effected by the higher solution temperature was found to be due to more complete solution of $CuAl_2$.

Reduction of iron impurity below 0.24 per cent was also shown to result in property improvement of sand-cast aluminum-copper alloys. A 4.5 per cent copper alloy specimen containing 0.24 per cent iron, solution treated and aged at normal temperatures, possessed mechanical properties of 33,000 psi ultimate tensile strength, 26,000 psi yield strength and 3 per cent elongation. Lowering the iron content to 0.03 per cent resulted in an improvement of mechanical properties to 43,000 psi ultimate tensile strength, 26,000 psi yield strength and 7 per cent elongation.

A substantial portion of the property improvement attributable to chilling normally heat treated aluminum-copper alloy castings was found to be due to the fact that chilling refines the size and distribution of intermetallic compounds in these alloys.

NOTE: Based on a thesis submitted by E. M. Passmore in partial fulfillment of the requirement for the Sc.D. degree, Department of Metallurgy, Massachusetts Institute of Technology.

*Senior Scientist, Avco Manufacturing Corp., **Assistant Professor and Professor, respectively, Massachusetts Institute of Technology.

INTRODUCTION

It has been recently shown that chilling, together with close control of other foundry variables, may be used to substantially raise the mechanical properties of aluminum alloy castings. For example, present specifications permit mechanical properties of 195 alloy castings (4.5% Cu, bal. A1) to average as low as 22,500 psi ultimate tensile,strength 20,000 psi yield strength and ¾ per cent elongation.[1] If foundry variables, (including chemistry, grain size, gas content, and heat treatment) are closely controlled, properties of the order of 37,000 psi ultimate tensile strength, 27,000 psi yield strength, and 3 per cent elongation may be produced in an unchilled 1-in. thick sand casting. If chills are added to the sand casting, the properties are raised to values as high as 55,000 psi ultimate tensile strength, 27,000 psi yield strength and 18 per cent elongation.[2]

The present work has been undertaken to determine if greater control of the solution-treating operation or of impurity content, might be effective in substantially improving the properties of sand-cast aluminum-copper alloys. If so, these techniques might be used in conjunction with or in place of chilling, to produce high strength-high ductility castings. A second objective of the investigation has been to gain, if possible, an insight into the basic mechanism whereby chills improve the mechanical properties of aluminum-copper alloy sand castings.

When aluminum-copper alloys solidify, they do so in a eutectic fashion. The phase diagram (Fig. 1) indicates that only alloys containing over 5.65 per cent copper should possess eutectic in their final microstructure, but in practice, due to "non-equilibrium" freezing in sand or chill molds, eutectic is found in alloys containing as little as 1/2 per cent copper.

The eutectic appears at grain boundaries and between dendrite arms (Fig. 2); it is made up largely of $CuAl_2$ intermetallic compound with some aluminum-copper solid solution intermixed. Because of the brittle nature of the $CuAl_2$, a relatively small amount of this compound at grain boundaries tends to reduce the strength and ductility of aluminum-copper alloys.

Fortunately, the grain boundary eutectic can be dissolved in alloys containing less than 5.65 per cent copper by proper heat treating. It is necessary, in theory, only to heat these alloys to temperatures above the line $\frac{aa}{aa}$ of Fig. 1 for a sufficient length of time (solution treat) and then water quench. Initial phases of this investigation conducted on 195 alloy (4.5 per cent Cu) indicated that normal solution treatments (960 F, 8-24 hr, water quench) do in fact nearly completely solutionize the cast alloy when *heavily chilled.* In unchilled sand castings, however, the $CuAl_2$ is in much more coarsely distributed form, and the same time and temperature of solution treatment leave considerable brittle compound undissolved (Fig. 8b illustrates a typical example).

In view of the foregoing, it was considered that a major reason why chills improve the mechanical properties of aluminum-copper sand castings might be that the chills make the alloy more amenable to heat treatment. A study was therefore undertaken to determine 1) if the brittle compound in unchilled alloys could be more completely dissolved by solution treating at high temperatures and for longer times than those commercially employed; and 2) if the more complete solution treatment of the intermetallic $CuAl_2$ would result in substantial property improvement of unchilled aluminum-copper alloys.

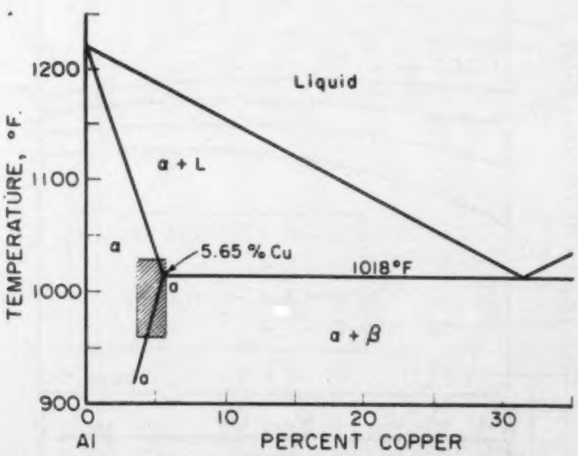


Fig. 1—Aluminum-rich portion of the aluminum-copper phase diagram. Shaded area represents range of solution treatment temperatures and copper contents studied.

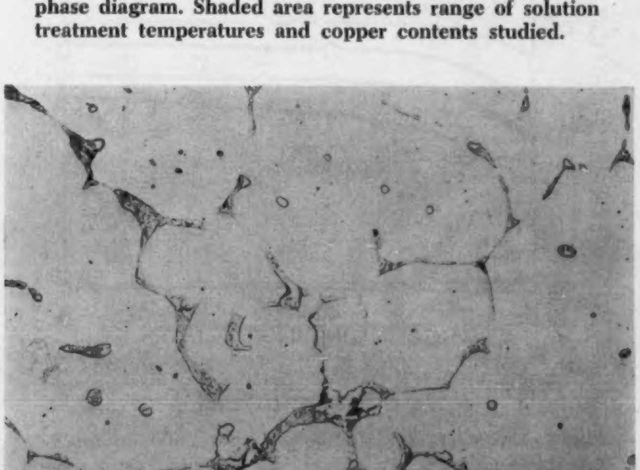


Fig. 2—Photomicrograph of aluminum–5 per cent copper alloy, ×150. (As cast).

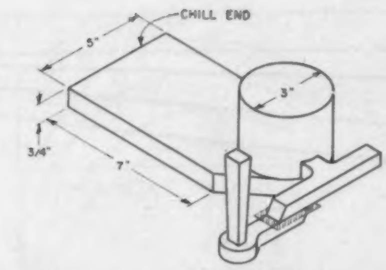


Fig. 3—Sketch of test pattern. Test bars were taken parallel to the chill face and at distances of 0.4, 1.4, 3.4, and 5.4 in. from the face.

A concurrent study was undertaken of the effects of another intermetallic compound—that caused by iron impurity. The compound formed by this impurity in aluminum-copper binary alloys is the needlelike Cu_2FeAl_7.[3,4] Investigation was conducted of the effects of this compound on mechanical properties of chilled and unchilled aluminum-copper alloys.

PROCEDURE

1) Test Casting and Melting Practice

The test casting used throughout this work is illustrated in Fig. 3; it is a sand-cast end-chilled plate, 5 in. wide by 10 in. long by 3/4-in. thick. The plate, for all tests, was end-chilled with a 2 1/2-lb copper chill molded in green sand. Four test bars were taken from each casting at distances of 0.4, 1.4, 3.4, and 5.4 in. from the chill. The bar at 0.4 in. represented a severely chilled section, and the bar at 5.4 in. was sufficiently far from the chill to nearly represent an unchilled section.

Melting stock was high purity virgin material. For most of the experimental work 99.9 per cent pure aluminum was used, but for the study of the effect of iron content on mechanical properties a 99.99 per cent grade of aluminum was employed. Copper of

TABLE 1 – CHEMICAL ANALYSES OF EXPERIMENTAL HEATS

Heat	Copper (%)	Titanium (%)	Iron (%)	Silicon (%)
a	3.7	0.16	0.07	0.15
b	4.25	0.15	0.08	0.16
c	5.15	0.15	0.06	0.15
d	5.8	0.14	0.05	0.13
e	4.7	0.11	0.03	ND
f	4.7	0.11	0.07	ND
g	4.7	0.11	0.11	ND
h	4.7	0.11	0.24	ND
i	4.5	0.12	0.03	T
j	4.5	0.12	0.09	T
k	4.5	0.12	0.20	T

ND = None detected
T = Trace

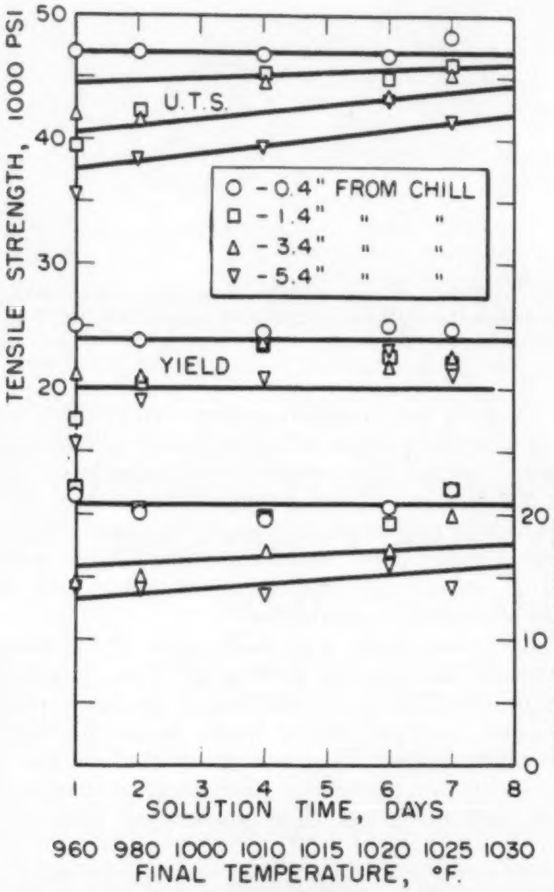


Fig. 4—Effect of varying solution treatments on mechanical properties of aluminum-3.7 per cent copper alloy. Heat a. After the above solution treatments (see text for full description) all specimens were water quenched and aged 14 hr at 310 F before testing.

99.9 per cent purity was used throughout; the melts were grain refined with an aluminum-titanium master alloy, and iron was added (when required) by an aluminum-iron master alloy. Chemical analyses of experimental heats are listed in Table I.

In melting, the high purity pigs were charged first, and master alloys added as soon as melting began. Degassing was accomplished with a special grade of dry nitrogen (-73 F dewpoint). Nitrogen was bubbled through the melt for 15 min at 1200 to 1300 F. Gas content was checked with a reduced pressure tester; the metal was held 5 min. to allow dross flotation and poured.

The only variation in this procedure was that the varying iron levels of heats e-h, and i-k were obtained by split tapping; a predetermined amount of aluminum-iron master alloy was added between each tap, and the metal degassed 5 min before pouring. Heats e-h, and i-k were each single melts.

2) Study of the Effect of Varying Solution Treatments

In order to study the effect of varying solution treatments on aluminum-copper alloys, four alloys were poured in the test pattern described above. The alloys centered around 195 alloy composition; they were 3.7, 4.25, 5.15, and 5.8 per cent copper. Eight test plates of each alloy were poured, and the four bars described were cut from each plate for test.

Solution treatment was carried out in a furnace specially constructed to produce uniform, controlled temperatures; temperature control was ±2 F. A standard solution treatment at 960 F (for 24 hr) was first given all specimens. For 16 of the bars (4 bars from each of four plates of different copper contents) this was the only solution treatment employed. Remaining bars were given progressively more intensive solution treatments. The last of these was a culmination of the others and will be described in detail. Sixteen specimens of four copper contents and four distances from the chill were placed in the furnace and heated to 960 F for 24 hr (as described); the temperature was then raised to 980 F and held for an additional 24 hr, then raised to 1000 F for another, and so on to 1010 F, 1015 F, 1020 F, 1025 F, and 1030 F. At the end this process, the 16 specimens had been in the furnace for 8 days. They were then quenched. Intermediate heat treatments between the two extremes cited were given by dropping one or more of the days at the higher temperatures. The final solution temperature for a given set of bars therefore varied from 960 F to 1030 F in the sequence given above. After solutionizing, all bars were water quenched.

Specimens were kept at room temperature for 2 to 3 weeks between solution treating and aging. Aging

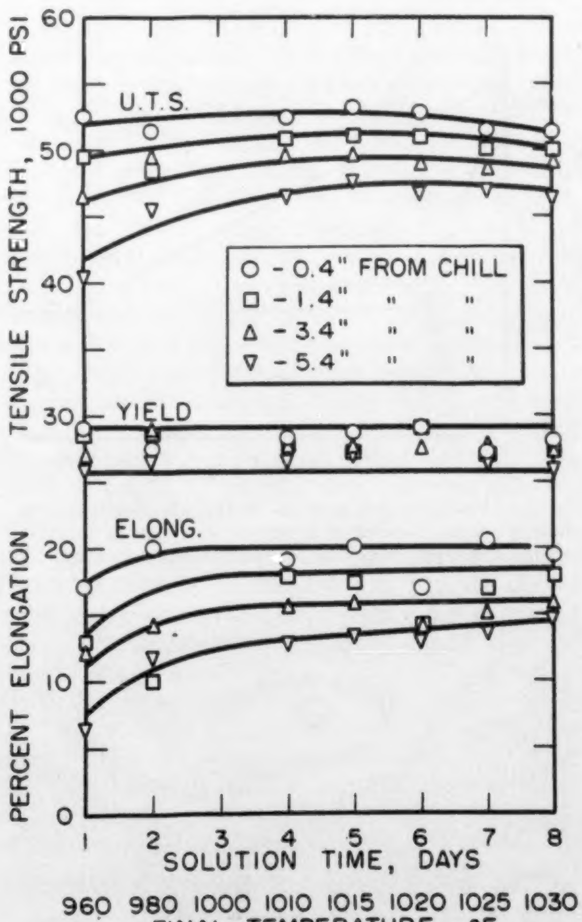


Fig. 5—Effect of varying solution treatments on mechanical properties of aluminum-4.25 per cent copper alloy. Heat b. After the above solution treatments all specimens were water quenched and aged 14 hr at 310 F before testing.

was carried out at 310 ± 10 F for 14 hr, in a commercial recirculating air furnace. Standard 1/2-in. diameter, 2-in. gage length test bars were machined from the test specimens and pulled. Yield strengths were taken at 0.2 per cent offset. Test data were plotted as mechanical properies versus final solution temperature, as shown in Figs. 4-7.

The effect of the solution treatments on the structure of the alloys was determined by examining the microstructure visually, and by X-rays (microradiography). Specimens for microradiography were prepared by polishing thin sections of the shoulders of selected test bars to 0.005-in. thickness. Radiographs were then taken using microfile film and suitable radiation.

3) Study of the Effect of Varying Iron Content

In order to study the effect of varying iron content on mechanical properties of aluminum-copper alloys, a series of approximately aluminum—4.5 per cent copper alloy plates were poured; iron content was varied from 0.03 per cent to 0.24 per cent.

All plates were heat treated 24 hr at 960 F, water quenched, and aged as described above. The four test bars were cut from the plates (Fig. 3) and tested. Mechanical properties were reported versus per cent

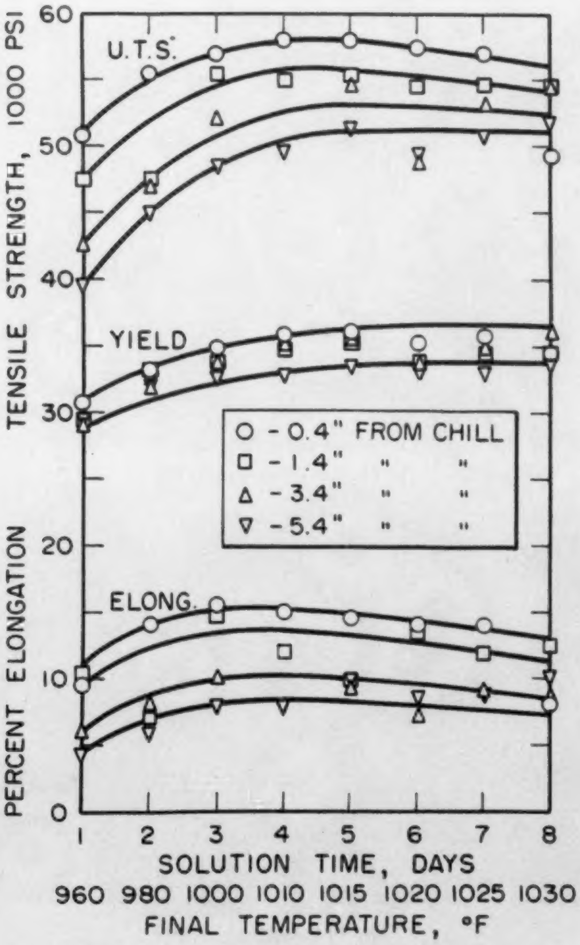


Fig. 6—Effect of varying solution treatments on mechanical properties of aluminum-5.15 per cent copper alloy. Heat c. After the above solution treatments all specimens were water quenched and aged 14 hr at 310 F before testing.

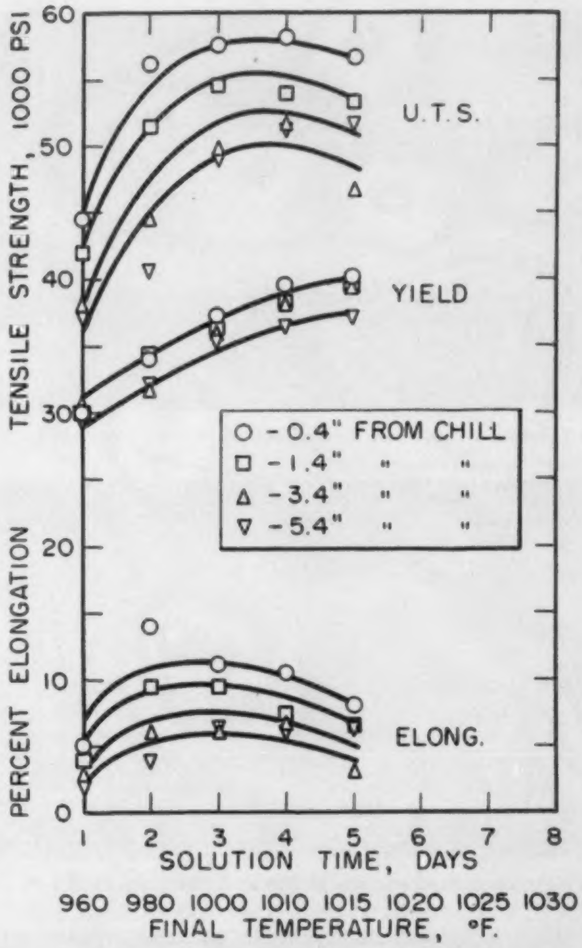


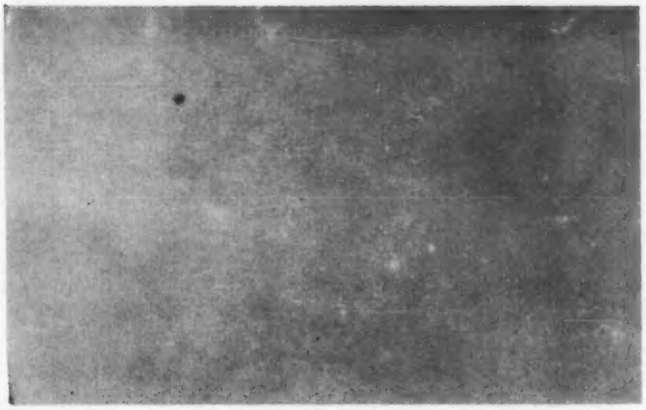
Fig. 7—Effect of varying solution treatments on mechanical properties of aluminum-5.8 per cent copper alloy. Heat d. After the above treatments all specimens were water quenched and aged 14 hr at 310 F before testing.

iron as shown in Fig. 11. Effect of iron on the microstructures was examined by metallographic techniques.

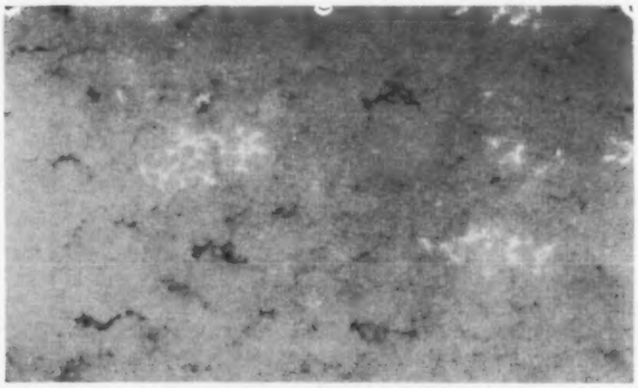
1) Effect of Varying Solution Treatments

The effect of the various solution treatments on the mechanical properties of the specimens tested is illustrated in Figs. 4-7. These show that increasing the solution treatment temperature of aluminum-copper alloys above 960 F generally increases the mechanical properties of the alloys. The improvements in mechanical properties are greater in the alloys of higher copper content. Improvements also tend to be greater for the metal several inches from the chill than for metal near the chill, especially at the lower solution times and temperatures. Even in an alloy of as low as 4.25 per cent copper, the improvement to be gained by intensive solution treating is substantial. The 4.25 per cent copper test bar furthest from the chill, solution treated at 960 F, yielded mechanical properties of 42,000 psi ultimate tensile strength, 27,000 psi yield strength, 7 per cent elongation. Increasing the final solution temperature to 1010 F raised these properties to 47,000; 27,000; 13.*

*The shorthand 47,000; 27,000; 13 is used to denote 47,000 psi ultimate tensile strength, 27,000 psi yield strength, 13 per cent elongation.



(a) Solution treated one day at 960 F, 0.4 in. from chill.



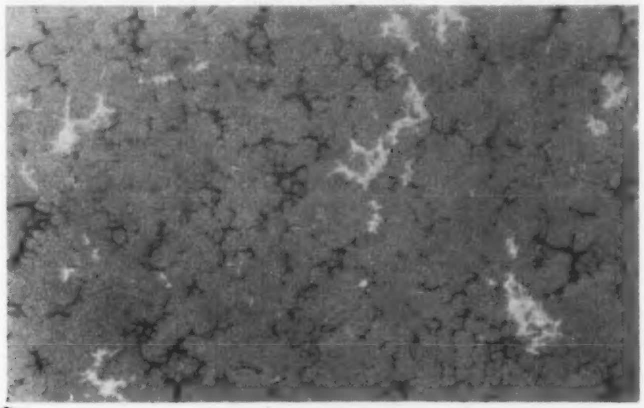
(b) Solution treated one day at 960 F, 5.4 in. from chill.

(c) Solution treated 4 days; final solution temperature, 1010 F; 5.4 in. from chill.

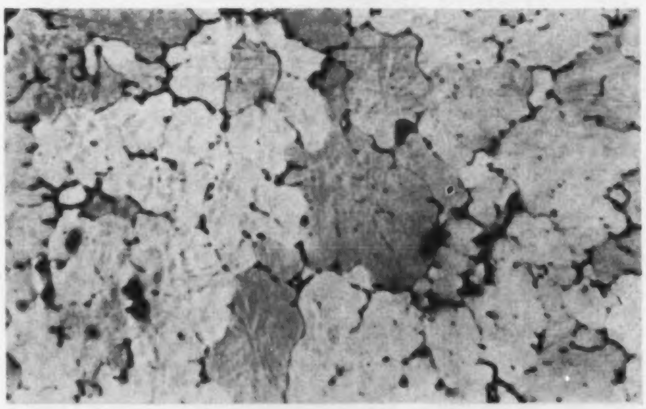
Fig. 8—Microradiographs showing the effect of distance from the chill and solution treatment on the structure of aluminum-4.25 per cent copper alloy. Heat b. ×16. Dark areas represent undissolved $CuAl_2$. Light areas represent microporosity.

In Fig. 8, microradiographs of the aluminum 4.25 per cent copper alloy illustrate how the increased solution treatment improves mechanical properties. After only a one day solution treatment at 960 F, no copper-rich particles are visible in the microradiograph of the metal near the chill (Fig. 8a.) Mechanical properties at this location are 52,000; 29,000; 17, and very little improvement is obtained here by any further solution treating (Fig. 5). In the more slowly cooled area of the casting, however, massive $CuAl_2$ particles are easily seen (Fig. 8b); mechanical properties of the test bar with this structure are 42,000; 27,000; 7. When the test bar in this (slowly cooled) location is heated for 4 days to a maximum temperature of 1010 F, essentially all the $CuAl_2$ is dissolved, and the mechanical properties correspondingly improve to 47,000; 27,000; 13.

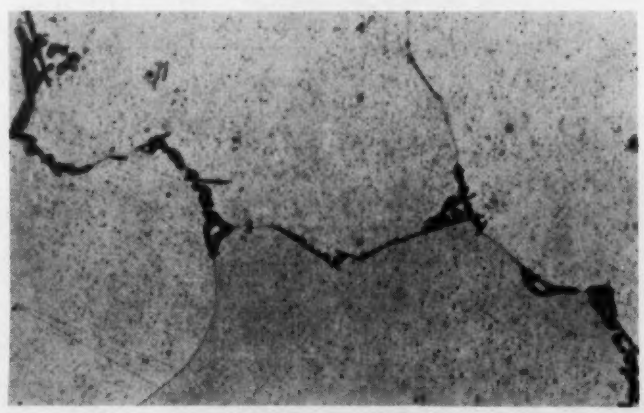
At the high levels of copper content the changes in mechanical properties with increasing solution treatment temperature can be correlated in a similar way with the solution of $CuAl_2$. As illustrated in Figs. 6 and 7, however, the properties of these alloys decrease at the excessively high solution temperatures employed due to localized melting, or "burning." Figures 9 and 10 illustrate the changes in struc-



(a) Microradiograph. ×18



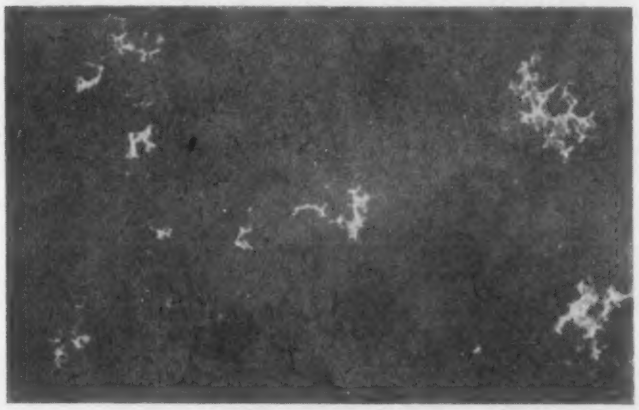
(b) Photomicrograph. ×25



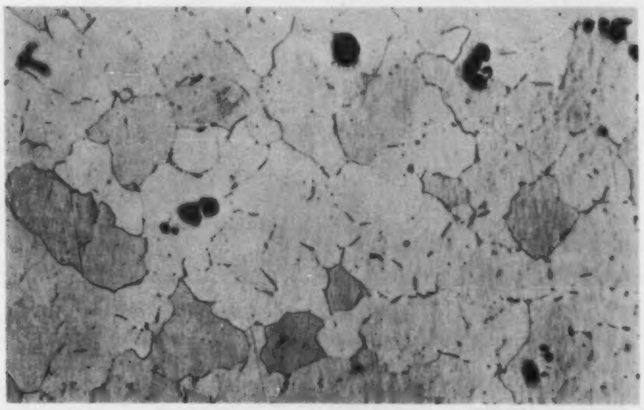
(c) Photomicrograph. ×200

Fig. 9—Structure of 5.15 per cent copper alloy, 5.4 in. from the chill. Solution treated one day at 960 F. Heat c. Dark areas in microradiograph and photomicrographs are largely $CuAl_2$. Some needlelike iron compound is also visible in Fig. 9 (c). Light areas of microradiograph represent microporosity.

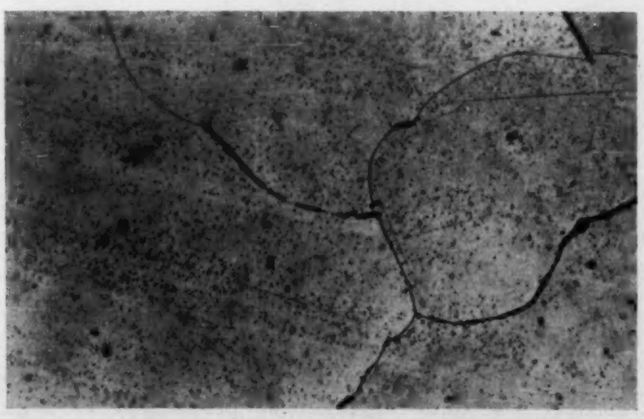
ture which occur by raising the solution treatment temperature of a 5.15 per cent copper alloy. Figure 9 shows the microradiographic and metallographic structure of the (slowly cooled) alloy solution treated one day at 960 F. Rather large amounts of $CuAl_2$ are apparent in the structure. Mechanical properties were 40,000; 29,000; 5. After 4 days solution treatment, with a maximum temperature reached of 1010 F mechanical properties of the alloy reached a maximum (Fig.6). At this point all the $CuAl_2$ was essentially dissolved, as shown in Fig. 8; properties were approximately 50,000; 33,000; 8.



(a) Microradiograph. ×18



(b) Photomicrograph. ×25



(c) Photomicrograph. ×200

Fig. 10—Structure of 5.15 per cent copper alloy, 5.4 in. from the chill. Solution treated 4 days, final solution temperature 1010 F. Heat c. Needlelike, dark areas of the photomicrograph at ×200 (Fig. 10c) are probably iron compound. Light areas of the microradiograph represent microporosity.

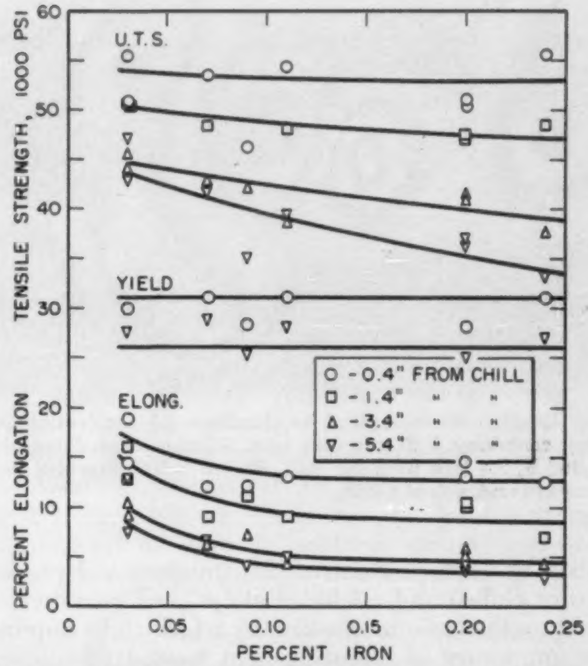


Fig. 11—Effect of iron on the mechanical properties of aluminum-4.5 per cent copper alloy. Heats e-k. All specimens solution treated at 960 F one day, water quenched, aged 14 hr at 310 F.

2) Effect of Varying Iron Content

The effect of iron content in the very low range of 0.03 per cent to 0.24 per cent is shown in Fig. 11. Mechanical properties of an alloy containing approximately 4.5 per cent copper and 0.24 per cent iron are 33,000; 26,000; 3, but reducing the iron content to 0.03 per cent increases these properties to 43,000; 26,000; 7. Solution treatment used for this study was 960 F for one day, for all specimens.

The structural difference between an aluminum-copper alloy containing 0.03 per cent iron and one containing 0.24 per cent iron is illustrated in Figs. 12 and 13. In Fig. 12, of the 0.03 per cent iron alloy, the only second phase visible (after heat treatment) is scattered undissolved $CuAl_2$. In Fig. 13, a photomicrograph of the 0.24 per cent iron alloy, a substantial number of needlelike Cu_2FeAl_7 particles are visible, in addition to the more rounded $CuAl_2$. The shape or amount of Cu_2FeAl_7 particles was not observed to be appreciably changed in the solution treatment cycle.

It is of interest to note in Fig. 11 that the iron particles are more deleterious to the tensile strength of the unchilled than the chilled metal. Figure 14 illustrates that this may well be due to the fact the chill tends to refine the size and distribution of the iron particles. Near the chill the Cu_2FeAl_7 particles are quite small and interspersed more or less evenly over the structure. At 5.4 in. away from the chill, the particles are coarser and more concentrated at grain boundaries where it might be expected they would be more deleterious to mechanical properties.

3) Effect of Chilling on Structure

The preceding studies of the effect of solution treat-

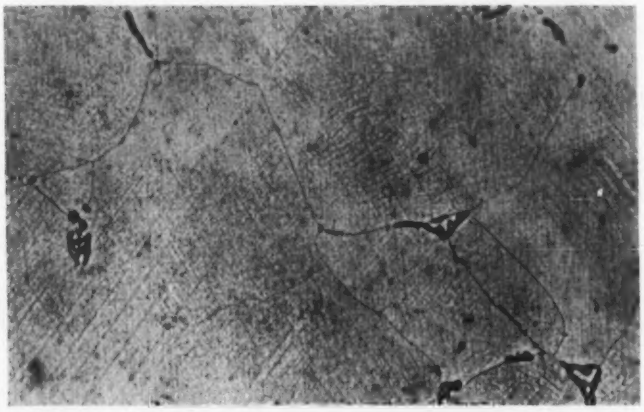


Fig. 12—Photomicrograph of an aluminum-4.5 per cent copper alloy containing 0.03 per cent iron. Solution treated one day at 960 F, 5.4 inch from the chill. Heat i. ×200. Rounded dark areas are undissolved $CuAl_2$.

ments and iron content on the structure and properties of chilled and unchilled alloys shed considerable light on the basic mechanism by which chills improve the properties of (normally heat treated) aluminum-copper castings.

Chills refine the size and distribution of the aluminum-copper intermetallic, permitting more complete solutionizing of this compound at standard solution treating temperatures. This effect alone accounts for a substantial portion of the beneficial effect of chilling, since the properties of the unchilled material may be so markedly improved by more complete solution treatment (Figs. 4-7). Chilling must have other beneficial effects, however, since complete solution treatment does not render the unchilled material quite as strong as the chilled material.

A second benefit of chilling is to refine the size and distribution of impurity intermetallics such as Cu_2FeAl_7 (Fig. 13). These impurities are not dissolved by heat treatment, but the fine distribution resulting from chilling is apparently less deleterious to mechanical properties than the coarse distribution occurring in unchilled sand castings (Fig. 11).

Chilling has two other effects on the structure which have not been extensively investigated herein. It reduces microporosity, as may be seen in Fig. 8, and this may be expected to result in some property improvement. Chilling also slightly reduces the grain size. For example the grain size of the 5.15 per cent copper bars furthest from the chill averaged about 0.19-millimeters diameter; those nearest the chill were about 0.16-millimeters diameter.

DISCUSSION

Solution treating aluminum-copper alloys at higher temperatures (and for longer times) than those normally employed has been shown to result in substantial mechanical property improvements. These property improvements have been correlated with the increased solutionizing of copper-aluminum intermetallic ($CuAl_2$) obtained at the higher solution treating temperatures.

In alloys containing 4.25 per cent copper or less, solution treatment temperatures above those normally employed had little effect on the chilled section of the casting. The chill acted to refine the $CuAl_2$ sufficiently so that it was completely dissolved during solution treatment. At distances away from the chill, however, solution temperatures above the normal 960 F substantially improved both the ultimate tensile strength and elongation of the alloys. In the alloys containing 5.15 per cent and 5.8 per cent copper, an improvement in mechanical properties due to high heat treatment was observed in both chilled and unchilled sections.

Dissolved iron impurities reduce mechanical properties of aluminum-copper alloys by forming needles of Cu_2FeAl_7. These needles are deleterious to mechanical properties in amounts even less than 0.24 per cent, and iron content should be kept to the minimum possible if maximum mechanical properties are desired. The iron particles are less deleterious to the properties of the chilled sections than the unchilled sections; apparently because the particles are of finer size and more even distribution in the chilled sections.

Chills markedly improve the mechanical properties of aluminum-copper alloy sand castings given normal

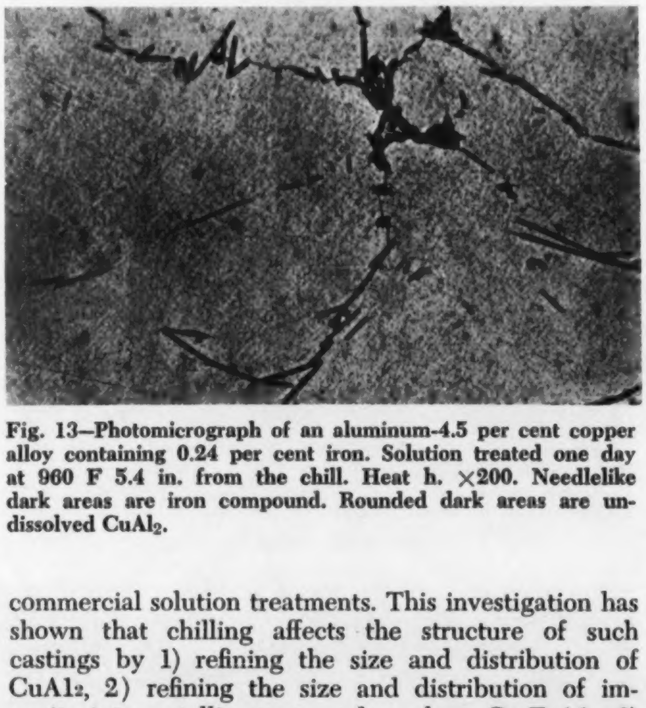
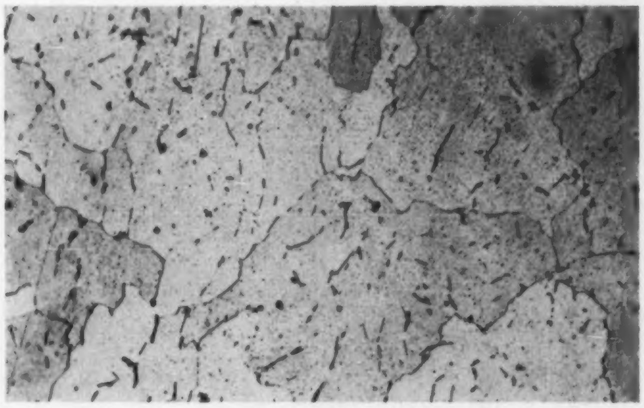


Fig. 13—Photomicrograph of an aluminum-4.5 per cent copper alloy containing 0.24 per cent iron. Solution treated one day at 960 F 5.4 in. from the chill. Heat h. ×200. Needlelike dark areas are iron compound. Rounded dark areas are undissolved $CuAl_2$.

commercial solution treatments. This investigation has shown that chilling affects the structure of such castings by 1) refining the size and distribution of $CuAl_2$, 2) refining the size and distribution of impurity intermetallic compounds such as Cu_2FeAl_7, 3) reducing microporosity, and 4) slightly reducing grain size. In this work, items 1) and 2) were shown to account for a substantial portion of the property improvement attributable to chilling aluminum-copper castings.

It is essential to note in closing that the work which has been presented here is of a basic, exploratory nature. As yet, no attempt has been made to convert the data to practical production of high strength-high ductility castings. Such a conversion may well be feasible, and indeed may offer some attractively high mechanical properties. For example, with a 5.15 per cent copper alloy, and suitable heat treatment, but without chills it should be possible to produce a casting with mechanical properties of 50,-



(a) 0.4 in. from chill

(b) 5.4 in. from chill

Fig. 14–Effect of distance from the chill on microstructure of aluminum-4.5 per cent copper alloy containing 0.24 per cent iron. Solution treated one day at 960 F. Heat i. Photomicrographs, × 140. Needlelike dark areas are iron compound.

000 psi ultimate tensile strength, 35,000 psi yield strength, and 8 per cent elongation. Since temperature is far more important than time in obtaining adequate solutionizing,[5] it should be possible to obtain complete solution treatment in much shorter times than those employed here, simply by raising the castings directly to the desired temperatures. However, no attempt has been made in this work to determine if the heat treatment necessary to obtain the above properties would be either feasible or justifiably economical in production. Two general practical conclusions may nonetheless be made. These are, that for production of high strength-high ductility aluminum-copper castings, iron content should be as low as practicable and solution temperature as high as possible without resulting in casting warpage or partial melting.

CONCLUSIONS

1) Increasing solution treating temperatures (and times) above those normally employed improves the mechanical properties of aluminum-copper alloys. Alloys studied contained from 3.7 to 5.8 per cent copper.
2) Mechanical properties of a slowly cooled aluminum—4.25 per cent copper alloy were 42,000 psi ultimate tensile strength, 27,000 psi yield strength, 7 per cent elongation after heat treating one day at 960 F. Using a step heat treating schedule with final solution temperature 1010 F, mechanical properties of 47,000 psi ultimate tensile strength, 27,000 psi yield strength, 13 per cent elongation were obtained. Greater improvements were obtained with alloys containing larger amounts of copper.
3) Heat treating a 4.25 per cent copper alloy chilled section at temperatures greater than those normally employed does not appreciably improve the mechanical properties. This is attributed to the fact that the chill sufficiently refines the $CuAl_2$ in this alloy that a normal solution treatment is able to essentially homogenize the alloy.
4) The increases in elongation and tensile strength obtained by intensive solution treating were due to the reduction in amount of undissolved $CuAl_2$ resulting from the solution.
5) In 5.15 and 5.8 per cent copper alloys, elongation and tensile strength go through maxima with increasing solution treatment time and temperature. The decreases in these properties after the maxima are due to localized melting of copper-rich regions.
6) Iron as an impurity lowers the mechanical properties of aluminum—4.5 per cent copper alloy even when present in amounts less than 0.24 per cent. The lower properties are due to the presence of needlelike Cu_2FeAl_7 particles.
7) Iron does not affect the mechanical properties of a chilled section of aluminum-copper alloy as much as it does a slowly cooled section. This is attributed to the fact the Cu_2FeAl_7 particles are finer and more evenly distributed in the chilled metal.
8) A substantial portion of the property improvement attributable to chilling of normally heat treated aluminum-copper castings is due to 1) refinement of the size and distribution of $CuAl_2$ intermetallic and 2) refinement of the size and distribution of impurity intermetallics.

ACKNOWLEDGMENT

The authors wish to express their appreciation to the Pitman-Dunn Laboratory, Frankford Arsenal, for support of this work.

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AMERICAN FOUNDRYMEN'S SOCIETY – PREPRINT NO. 58-34
This paper has been approved for presentation at the 62nd Annual Meeting of the American Foundrymen's Society, to be held in Cleveland, Ohio, May 19-23, 1958. The Society reserves all rights for publication either prior to or subsequent to presentation, and is not responsible for statements or opinions advanced herein.
WRITTEN DISCUSSION IS SOLICITED

IMPROVEMENT OF CASTINGS BY PRESS FORGING

By

A. H. Murphy,* L. L. Clark, and W. Rostoker***

ABSTRACT

It is demonstrated that significant increases in the proof, yield, and ultimate strengths of cast and heat-treated alloys can be achieved by cold or warm deformations of the order of 15-30 per cent. Work was confined to two high-strength aluminum casting alloys and one magnesium alloy. It was shown that the strength gains are made at some sacrifice in ductility so that this process is not advantageously applicable to all alloys. Also, in some instances nonconventional aging practices can accomplish the same thing. A description is given of methods for producing precision cast dies for use in press forging of castings. Results are given on the press forging of a commercial magnesium casting which confirm the magnitude of improvement shown by test coupons.

The competition between forgings and castings is usually determined by price, mechanical properties, volume output and rate of entry into manufacture. The disparity in mechanical properties between castings and forgings is often the factor that rules the casting out of acceptance.

This paper describes a program of work designed to improve the mechanical properties of castings by small deformations below the recrystallization temperature using a press forging procedure which should not seriously increase the cost of the final product. The results indicate a useful hybrid of the two basic operations. The program was sponsored by the Manufacturing Methods Branch of the Air Materiel Command, U. S. Air Force.

The research program is separable into a number of consecutive phases. The fundamental verification of the value of press forging was performed on cast coupons whose initial cast or preheat-treated forging was performed on cast coupons whose initial cast or preheat-treated mechanical properties were very uniform. A large casting was designed from which numbers of specimens could be cut, all of which were equivalent to a high degree.

The coupons were forged between flat, preheated platens, the pressure-deformation characteristics being concurrently determined. Tensile specimens machined from the deformed coupons were tested destructively to provide proof stress, yield stresses, ultimate strength, and elongation at fracture. The optimum conditions for enhancement of mechanical properties were duplicated on an actual commercial magnesium casting.

The casting itself was tested for both service deflection and fracture stresses. Since an appreciable part of the cost of a forging derives from the capital investment in dies, it was deemed necessary, in order to preserve the price range of the casting, to produce cheap dies. A system for the precision casting of die cavities using hardenable beryllium copper was developed. These cast dies were used successfully to close-die, press forge the magnesium casting.

Work was concentrated on two aluminum alloys, 356* and 220*, and on one magnesium alloy, AZ92.* All three find general use in high-strength casting applications. Both the aluminum 356 alloy and the magnesium AZ92 alloy are used in their heat-treated conditions. The aluminum 220 alloy, although capable of aging, is generally used in the solution-treated state.

PRODUCTION OF CAST TEST BARS

The test coupons for press forging were bars 1-in square by about 8 in. long. Each coupon was to have two opposed cast surfaces to mate with the die surfaces, thus simulating the actual frictional conditions in a production operation. These test bars could have been cast in test bar molds. To avoid criticism that the press forging was applied to sounder metal than is normally encountered in castings, the test bars were cut from a cast plate 12-1/2 in. x 8 in. x 1 in.

Problems were encountered in the design of gating, risering, and chill systems which would permit the production of plates whose soundness and mechanical

*Metals Research Department, Armour Research Foundation of Illinois Institute of Technology, Chicago.
**Presently at Fansteel Metallurgical Corp., Muskogee, Okla.

*Analyzed compositions:
Al 356 – 7.03 Si; 0.03 Cu; 0.33 Mg; 0.13 Ti; 0.20 Fe; 0.04 Zn
Al 220 – 9.8 Mg
Mg AZ92 – 9.2 Al; 2.0 Zn; 0.14 Si; 0.18 Mn

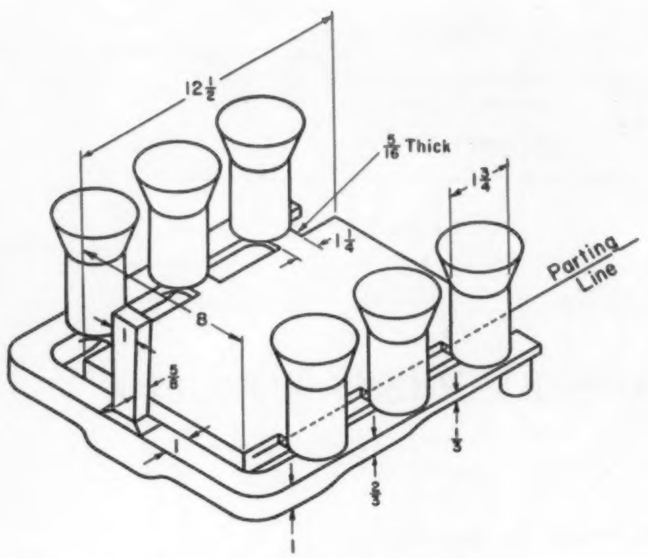


Fig. 1—Design of final aluminum 356 alloy casting.

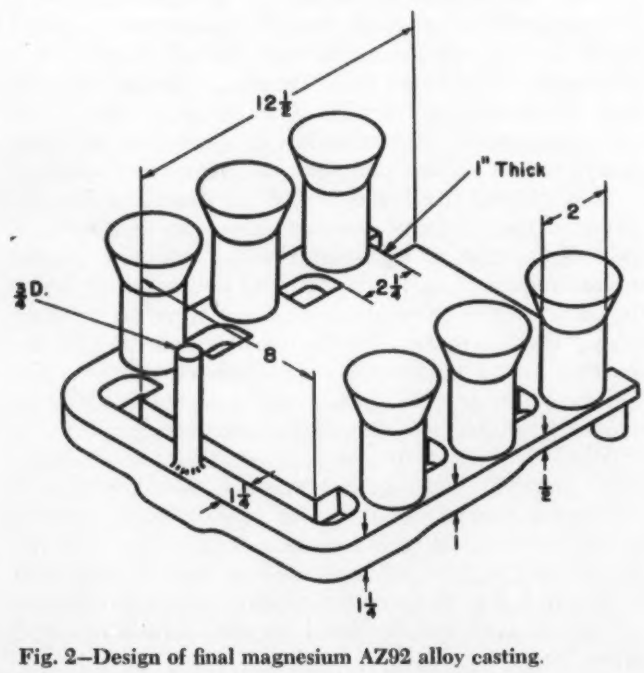


Fig. 2—Design of final magnesium AZ92 alloy casting.

properties were closely uniform throughout. The final designs for casting aluminum 356 plates and for magnesium AZ92 plates are shown in Figs. 1 and 2, respectively.

The casting behavior of the aluminum 220 alloy was found to be more nearly like that of magnesium than aluminum in many respects. The plate casting design in Fig. 2 was therefore used. To produce the correct freezing pattern it was necessary to use chills on the drag half of the mold located symmetrically about the center line of the plate. In the case of Al 220 alloy, the chill was of cast iron, 12 in. long x 3 in. wide x 1 in. thick.

In magnesium foundry practice it is customary to use a cast iron chill which is scored and coated with a chill wash. For the present purposes, this produced a cast surface which was unsuitable for comparative press forging. Elimination of the scoring in the chill

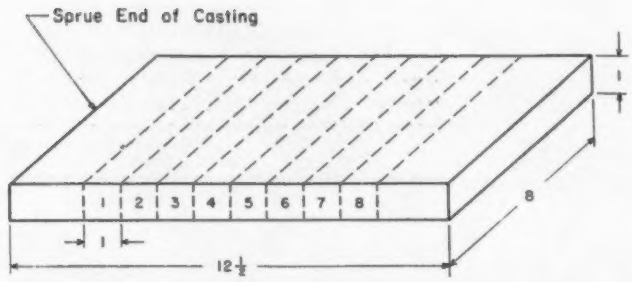


Fig. 3—Plate as cut from final casting and method of cutting and numbering test bars from the casting.

caused large surface defects in the casting which gave the appearance of gas bubbles.

No drying system or chill wash system was found to eliminate this. Various treatments and geometries of cast iron chill were attempted with no success. The use of copper, graphite, magnesium, aluminum, and stainless steel was tested as a replacement for cast iron. In all but the first instance, copper, the same bubbly surface was encountered.

For reasons which are not understood, copper chills permitted the production of castings with satisfactory surface. Interestingly enough, copper-plated chills proved to be unsuitable substitutes for solid copper chills. The final shape of copper chill was a T-section, with 2-3/8 in. x 1/8-in. flat and about 1 in. x 1 in. leg. This permitted castings of good surface, soundness, and grain size.

The pattern of sectioning of the cast plates is shown in Fig. 3. The ends were discarded. In a series of about 40 specimens the reproducibility of properties from plate to plate and from specimen to specimen within a plate was evaluated. The data on this, using test pieces as shown in Fig. 4, are summarized in Table I.

The evidence is that the quality control of the specimen blanks was an adequate basis for a press forging research program. In general, the average level of mechanical properties was about that encountered in commercial castings. The square cross section of the tensile test pieces would be expected to lower strengths and ductilities somewhat.

The compressive stress-strain behavior under simulated forging conditions is of concern to the general

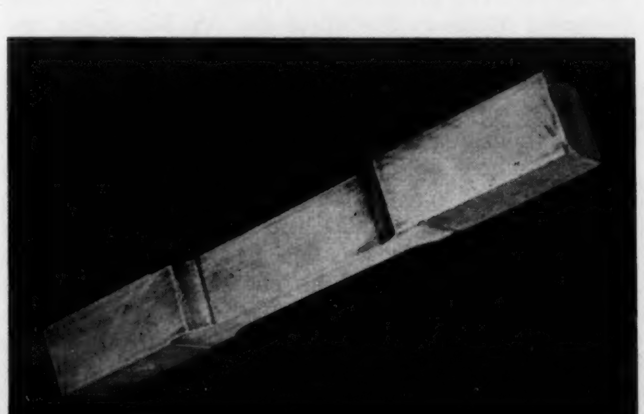


Fig. 4—Illustration of test piece machined from cast and pressed blanks.

TABLE 1 – UNIFORMITY OF TENSILE PROPERTIES IN CAST TEST PLATES

Alloy	Tensile spread, psi	0.2% yield strength spread, psi	0.1% yield strength spread, psi	Proof stress spread, psi	Elongation spread, %
Al 356-T6	33,700-37,300 (90%)*	25,200-29,000 (100%)	22,500-27,100 (100%)	16,500-21,300 (92%)	2.5-4.5 (89%)
Al 220-T4	28,000-33,000 (100%)	20,000-25,000 (90%)	19,000-24,000 (97%)	15,000-20,000 (94%)	7-13.5 (90%)
Mg AZ92-T6	27,000-31,100 (90%)	17,000-19,700 (97%)	14,000-16,200 (97%)	8,000-10,500 (97%)	1-2 (90%)

Heat Treatment Procedures

Al 356-T6—solution treated at 1000 F for 12 hr, water quenched, aged at 300 F for 4 hr.
Al 220-T4—solution treated at 765 F for 14 hr, water quenched.
Mg AZ92-T6—solution treated at 765 F for 6 hr, cycled to 665 F for 2 hr, cycled to 765 F for 10 hr, air quenched, aged at 500 F for 4 hr.
*Percentage of specimens in the quoted spread of properties.

purpose of developing the process of press forging of castings. One can expect the pressure-deformation characteristics of an alloy to depend on temperature of pressing, height-to-width ratio of the specimen, and frictional conditions (surface roughness and lubrication).

Each of these factors has been investigated in some detail. The testing arrangement is shown in Fig. 5. The press was 1000-ton capacity. The flat-faced die blocks mounted on the press platens were heated by inset cartridge elements. The 8 in. x 1 in. x 1 in. test blocks were preheated in a separate furnace before insertion between the die blocks. The pressing experiments were conducted isothermally.

All coupons were pressed with the as-cast surfaces in contact with the die faces. No lubrication was used except where specifically described. Pressing temperatures in the range of room temperature to the peak aging temperature were used. The cast coupons were heat treated prior to forging either to the solution-treated or fully aged state. Pressing speeds in this work were set at about 0.5 in./min. Within the practical range of pressing speeds this factor should have only a minor influence on requisite pressures. All pressures reported have been corrected to the final cross-sectional area of the specimen.

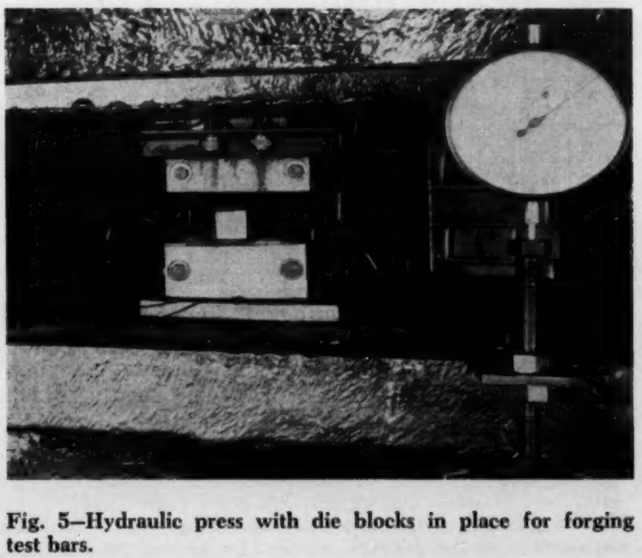


Fig. 5—Hydraulic press with die blocks in place for forging test bars.

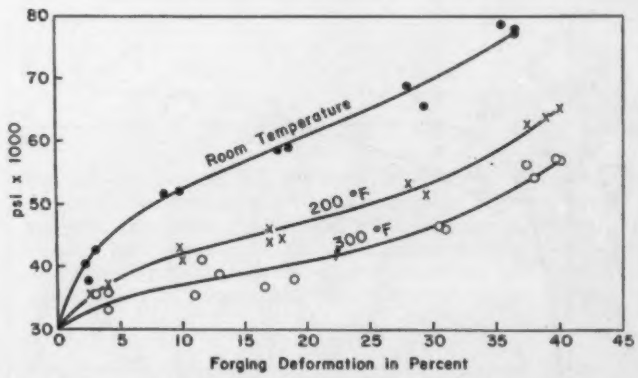


Fig. 6—Per cent deformation obtained by forging pressures on Al 356 alloy at three forging temperatures. Samples forged in solution-treated condition. Height-to-width ratio of samples 1:1. No die lubricant used.

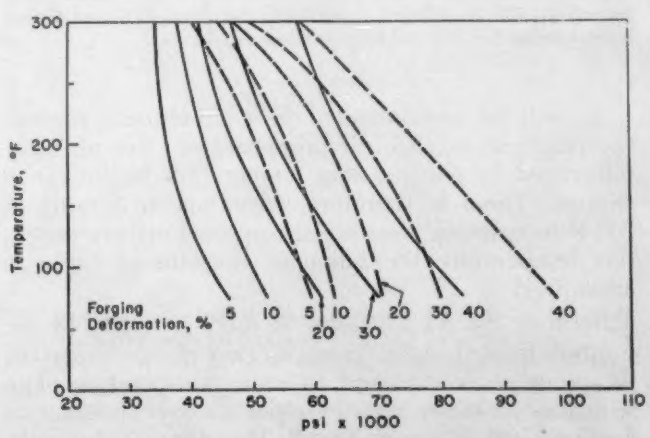


Fig. 7—Relationship between temperature and forging pressures for Al 356 alloy. No lubricant used. Height-to-width ratio of specimens 1:1. Solid lines refer to solution-treated condition; dashed lines refer to the aged (T6) condition.

The most detailed study of pressing behavior was concentrated on the Al 356 alloy. Pressure-deformation curves were derived for three temperatures, for both the solution-treated and T6 aged condition and for deformation ranges from 0-40 per cent reduction in thickness. A series of specimen curves are shown in Fig. 6. A graphical summary of the results for all combinations of degree of deformation, temperature, and state of heat treatment is given in Fig. 7.

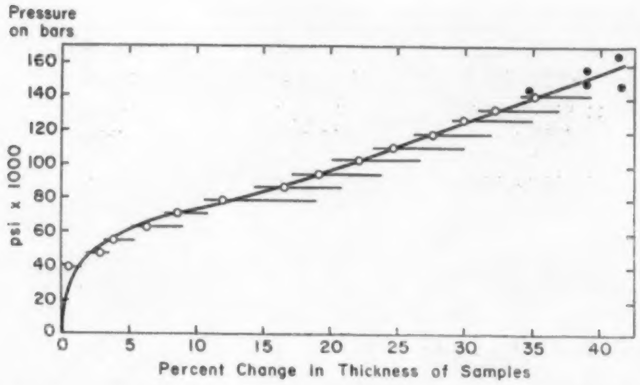


Fig. 8—Pressure-Deformation Relationships for Al 220 alloy forged at room temperature. Horizontal lines represent spread in measurements; circles represent best average data.

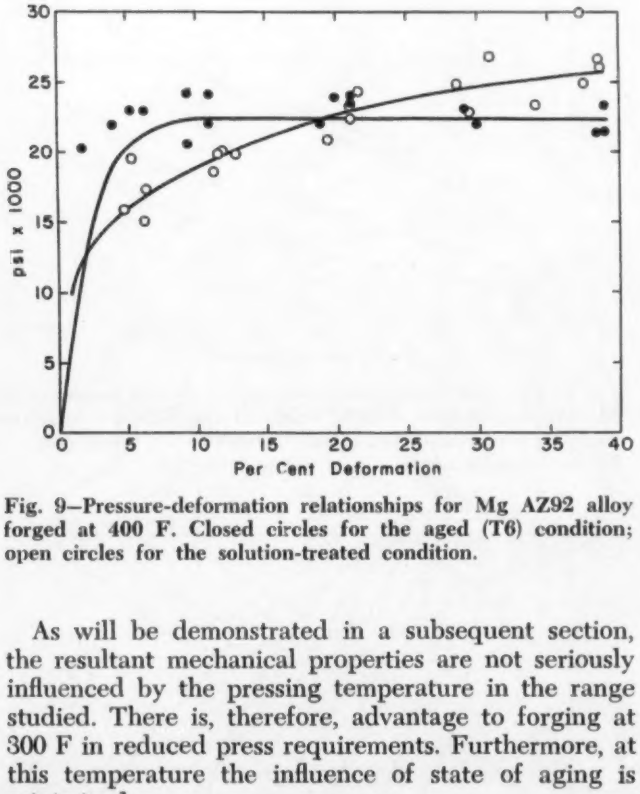


Fig. 9—Pressure-deformation relationships for Mg AZ92 alloy forged at 400 F. Closed circles for the aged (T6) condition; open circles for the solution-treated condition.

As will be demonstrated in a subsequent section, the resultant mechanical properties are not seriously influenced by the pressing temperature in the range studied. There is, therefore, advantage to forging at 300 F in reduced press requirements. Furthermore, at this temperature the influence of state of aging is minimized.

Because the Al 220 alloy is used generally in the solution-treated state, press forging of specimens of this alloy were confined to room temperature. The requisite pressures for 0-40 per cent reductions in thickness are shown in Fig. 8. This alloy is obviously stiffer in forging than Al 356.

The Mg AZ92 alloy at low temperatures has only a limited capacity for press reduction; a 45 degree fracture results thereafter. Only above 300 F can a large reduction be tolerated. A pressing temperature of 400 F was chosen for study; this is 100 F below the aging temperature for the T6 condition. The pressure-deformation curves are given in Fig. 9.

Apart from temperature and prior thermal history of the alloy, the pressure-deformation relations may be affected by geometry in terms of the height-to-width (or diameter) ratio and by the existence of lubricants between the casting and contacting die faces. The height-to-width ratio governs that proportion of the total volume of the specimen under the deformation which is under the restraint of the frictional forces at the casting-die interface.

Such restraint acts to raise the apparent yield stress. An example of the influence of this ratio on the requisite deformation pressures for magnesium alloy bars pressed at 400 F is shown in Fig. 10. Clearly a height-to-width ratio of less than 0.3 will necessitate excessively high forging pressures. It is well to be mindful that the height-to-width ratio changes during forging in the direction of lower values. Thus, a given section may be geometrically satisfactory initially but by spreading may become prohibitively difficult to continue to work.

A number of colloidal graphite lubricants, molybdenum disulfide, and silicone oil lubricants were tested for their influence on the deformation pressures of the magnesium alloy at 400 F. In all instances reduction of the friction had no significant effect in reducing the deformation pressures. Effects were observed on the spreading characteristics of the coupons—that is, lubricated specimens tended to spread more uniformly.

In general, the requisite press capacities for commercial castings as indicated by the results for the three alloys are not beyond practical limits. This is especially true when it is considered that selective press forging of critical areas of a casting may be all that is needed to improve service performance.

MECHANICAL PROPERTIES OF PRESS-FORGED SPECIMENTS

The pressed bars were machined to test pieces with a rectangular test cross section. Specimens which, prior to press forging, were in the solution-treated state were given the appropriate aging heat treatment cycle. There are a variety of ways in which the data can be meaningfully presented, but space limitations preclude all but the most interesting.

A typical trend of tensile properties of the Al 356 alloy with degree of press forging is illustrated in Fig. 11. The temperature of press forging in the range R.T.-300 F did not have much influence on the tensile properties, as shown in Fig. 12. The rate at which strength is enhanced by degree of deformation is greater when the T6 condition is the state prior to

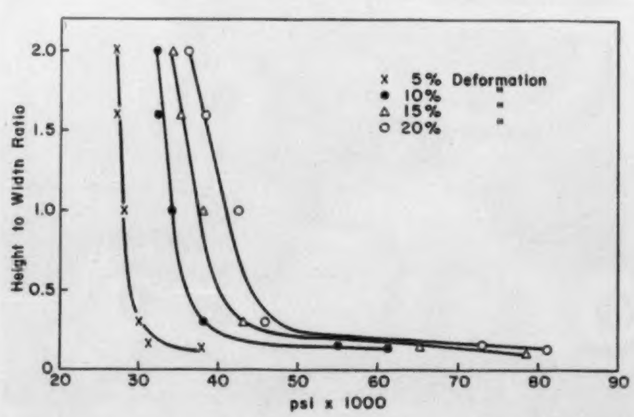


Fig. 10—Effect of height-to-width ratio of the forged Mg AZ92 test coupons on the pressure required for various deformations.

forging (Fig. 13), but the rate of decline of ductility is also greater.

There is no simple preference for the aged prior condition for forging as compared to the solution-treated state. This is obvious from the manner of presentation of the results in Fig. 14. For small increments in strength the loss in ductility is less for the prior aged condition. For large increments of strength, the loss in ductility is less for the prior solution-treated condition.

The price in ductility paid for the gains in strength by press forging of the Al 356 alloy was disappointing. Actually, the aging cycle for the T6 condition does not yield peak aging. If the aging heat treatment is prolonged, strength levels comparable to those shown in the graphs can be obtained with the same loss in ductility.

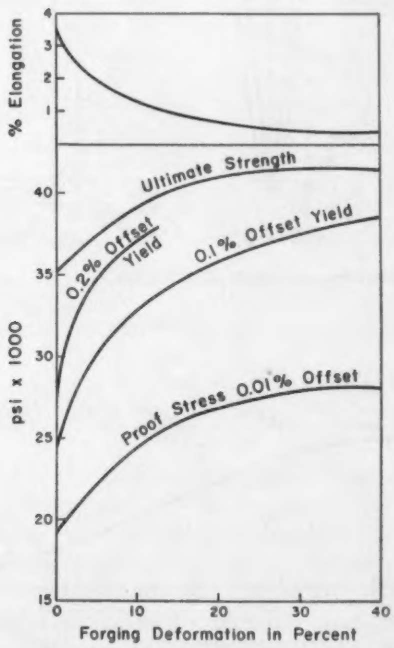


Fig. 11—Physical properties of Al 356 alloy press forged in the aged (T6) condition. Forged at room temperature.

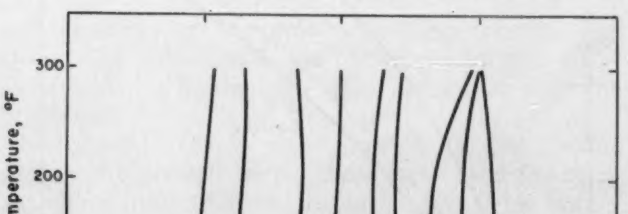


Fig. 12—Effect of forging temperature on the physical properties of Al 356 alloy given different forging deformations. Data obtained from samples forged in solution-treated condition and then aged (T6).

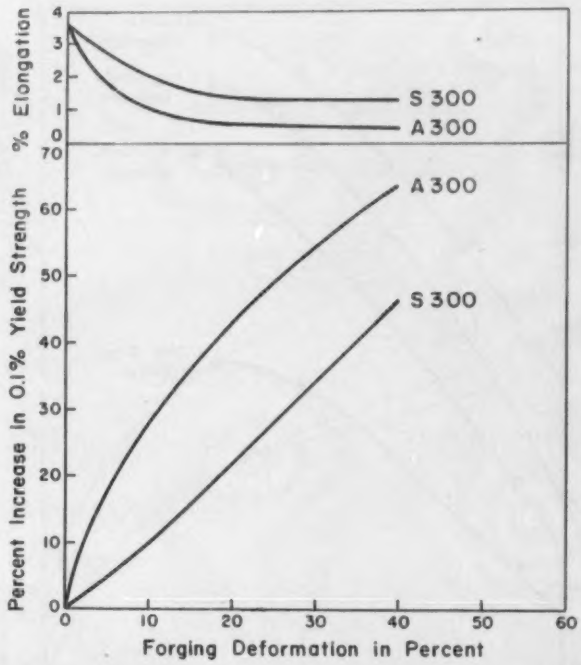


Fig. 13—Increase in 0.1 per cent offset yield strength vs forging deformation and corresponding change in per cent elongation for Al 356 alloy forged at 300 F. Curves A300 for alloy in the aged (T6) condition; S300 data for alloy in the solution-treated condition and aged subsequently to forging to (T6) condition.

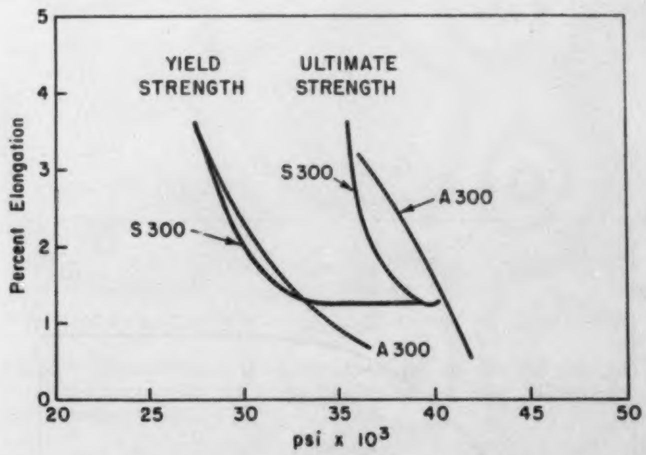


Fig. 14—Combinations of ultimate strengths and 0.2 per cent yield strengths with elongations obtained by press forging the Al 356 alloy at 300 F. S300 data for alloy forged in the solution-treated condition and then aged to the (T6) condition; A300 data for the alloy forged in the aged (T6) condition.

Obviously, if these combinations of strength and ductility are desirable, heat treatment is the easier way to produce them. This would not be true where it is desired to have the bulk of the casting in the T6 condition and selected areas at higher strength levels. Critical areas such as bosses or hubs could be press forged while maintaining standard properties in most of the casting. There is a parallel in the selective hardening of steel parts by induction heating or carburizing.

More encouraging results were obtained with the Al 220 alloy. It is evident from Fig. 15 that this alloy responds well to press forging. An increase in 0.2 per

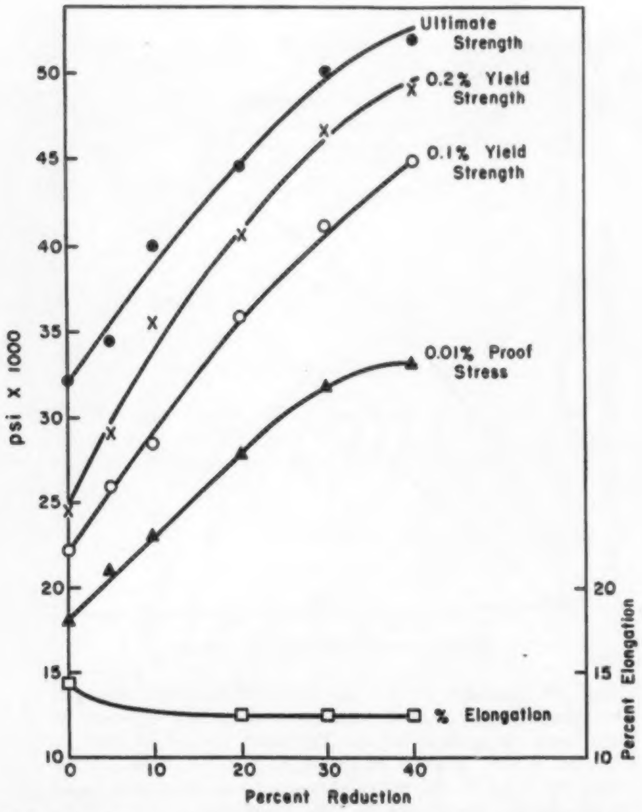


Fig. 15—Effect of forging deformations on the mechanical properties of Al 220 alloy forged in the (T4) condition.

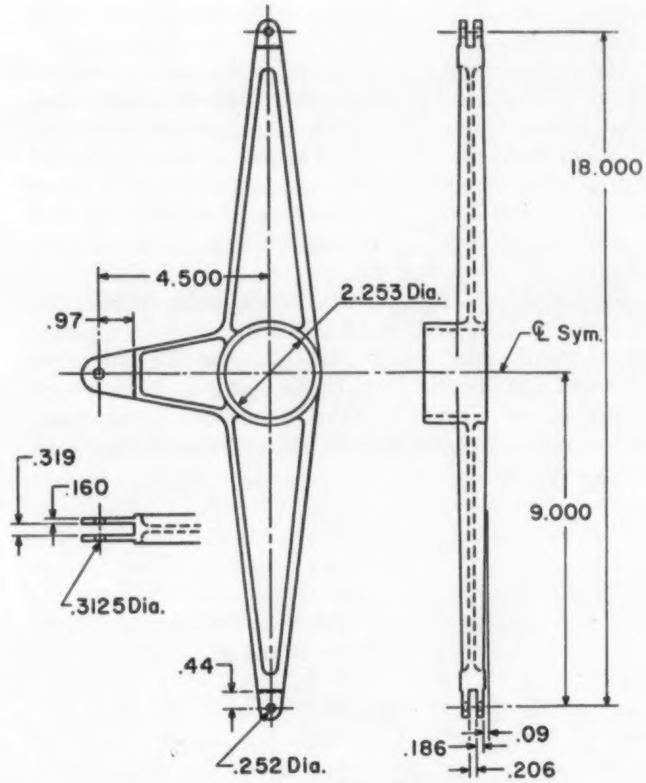


Fig. 17—Magnesium casting of AZ92 alloy.

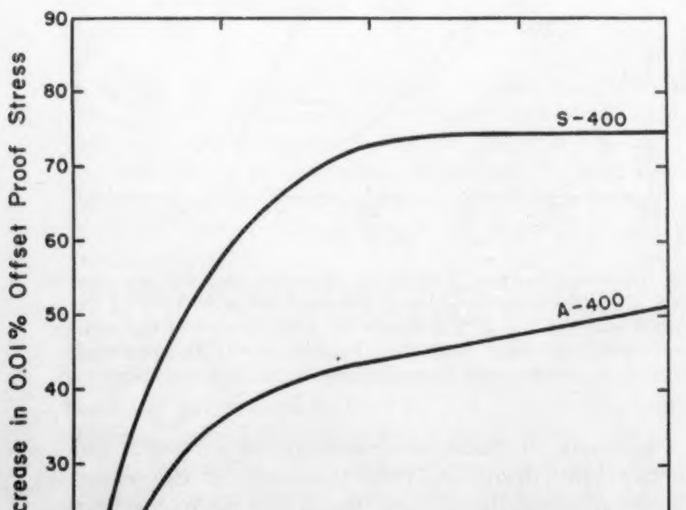


Fig. 16—Per cent increase in proof stress of Mg AZ92 alloy by press forging (T6) condition.

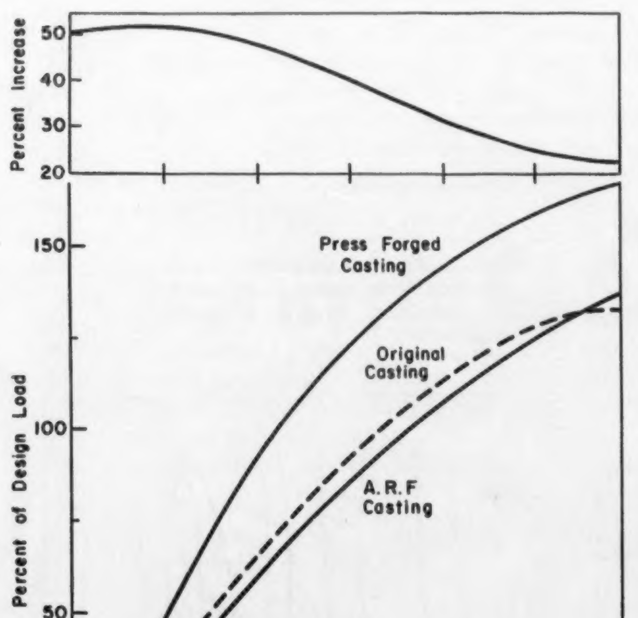


Fig. 18—Deflections under load and increases in load-sustaining capacity of cast and press forged magnesium elevator arm (T6) condition.

cent yield strength from 24,500 psi to 49,000 psi and the retention of 7 per cent elongation make a press-forged casting with properties that surpass many forgings. In many cases a complete casting could be forged about 20 per cent with a resultant gain of 65 per cent in the yield strength and a 50 per cent gain in tensile strength. In other castings, critical areas could be forged the full 40 per cent with a resultant gain of 100 per cent in the yield strength and 64 per cent in tensile strength. These enhanced properties could not be achieved by heat treatment.

The magnesium AZ92 alloy also responded well to the press forging treatment. As illustrated in Fig. 16, forging in the solution-treated state proved most advantageous to proof stress improvement. This also held true for tensile and yield strengths. A forging deformation at 400 F of 20 per cent was adjudged optimum for this alloy. The following improvements in properties were realized:

	As-Cast and heat treated (T6), psi	Press forged and heat treated (T6), psi	Improvement, %
Proof stress	9,400	16,200	72
0.1% yield strength	15,200	24,000	58
0.2% yield strength	19,800	27,800	43
Ultimate strength	29,500	35,000	19
% elongation	1.9	1.9	no change

Heat treatment cannot duplicate this measure of improvement.

PROPERTIES OF A PRESS-FORGED MAGNESIUM CASTING

In order that the conclusions drawn from the deformation of cast coupons not be regarded as interesting abstractions, it was considered desirable to demonstrate their practical validity on an actual casting in use as an aircraft component. The casting chosen and illustrated in Fig. 17 is an elevator arm. The alloy in use is magnesium AZ92. The hub, ribs, and raised bosses are typical features of many castings.

Press-forged castings and undeformed castings of the same dimensions were destructively tested in a test fixture designed to simulate the direction and magnitude of service loads. The original production castings were used for press-forging experiments. The 20 per cent reduction in the closed die forging operation yielded a finished part with somewhat different dimensions.

Redesigned castings were produced to the dimensions of the pressed parts. These were used for comparison of deflection and rupture loads. The results of these tests are summarized in Figs. 18 and 19. Clearly, the early favorable results on cast coupons were duplicated in the actual casting. Tensile specimens taken from the rib section of the various parts showed the following comparative properties:

	Production Part	ARF Cast Part	Pressed Part
Ultimate strength, psi	40,800	39,800	47,300
Yield strength, psi	24,300	25,200	35,000
Elongation, %	3	2.5	2.5

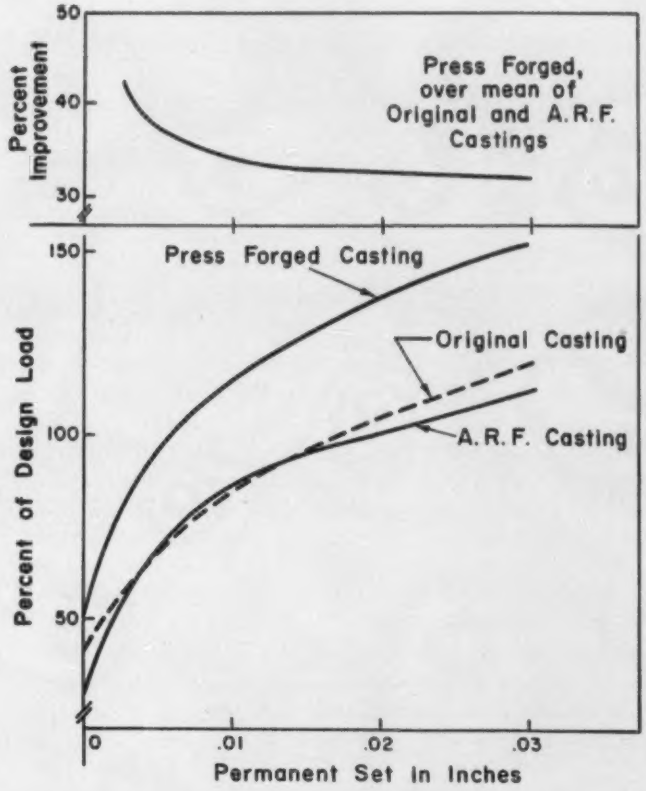


Fig. 19—Effect of press forging on the permanent deformation under load of magnesium elevator arm (T6) condition.

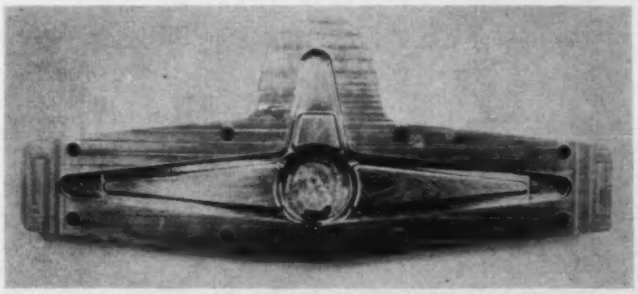


Fig. 20—Illustration of the upper half of the die set cast in beryllium copper for the press forging of the cast magnesium alloy elevator arm.

PRODUCTION OF CAST DIES FOR PRESS FORGING

The objective of improvement of castings by press forging without substantial increase in cost would be difficult to reach if the normal expenditures of die sinking had to be borne. It was therefore within the province of this research program to attempt to produce the dies necessary for the forging of the magnesium elevator arm by a casting process.

Dies with the cavity detail and surface of the as-cast state were successfully produced from beryllium copper. The castings for the die cavities were made using a sillimanite facing on a green sand mold. The sillimanite shell was produced by the Shaw process, the firing being performed by means of a torch. Pouring temperatures for these castings was 2000 F.

The castings produced had excellent surface finish and were dimensionally accurate to a high degree. Machining was limited to surface finishing the top and

bottom of the die to provide parallel surfaces. Some minor machining was performed in the cavity at the extreme ends; otherwise the die was used as-cast. The dies were heat treated to Rc = 40. The upper half of the die set is illustrated in Fig. 20.

More than 100 castings were forged with this die set at 400 F using a silicone oil die lubricant. As judged by the dimensions of successive forged castings, there was no apparent wear in the die set.

SUMMARY

It has been demonstrated that substantial increases in the yield and ultimate strengths of castings can be achieved by the application of relatively small deformations applied either cold or warm. The work thus far has been confined to two high-strength aluminum casting alloys and one magnesium casting alloy. Strength improvements of the order of 25-70 per cent have been realized for compressive deformations of 10-30 per cent. By the use of low-cost cast dies these improvements should not incur a large increase in the cost of the casting.

The improvements in strength cannot be gained without some expenditure of ductility. In the case of an aluminum alloy with a high reserve of ductility in the cast and heat-treated state, this expenditure should not detract from the engineering acceptance of the casting. In the case of the magnesium alloy which in its cast and heat-treated state has an intrinsically low ductility, there was actually no accurately measurable loss in ductility.

With the highly heat treatable Al 356 alloy, strength gains obtainable by press forging can also be developed by unconventional heat treatment. The deterioration in ductility is also the same. Obviously, in this instance, press forging would have value only where selective strength enhancement is desirable. In general, it would seem that press forging of castings is most advantageously applicable to alloys which are either non-heat treatable or only moderately so.

The pressures necessary to develop the requisite deformations are reasonably low particularly when forging is done at about 300-400 F. The choice of elevated temperature must lie below the peak aging temperature if such exists, or at least below the recrystallization temperature. The magnitude of the strength enhancement is independent of the temperature of forging below the peak aging temperature. There are geometric conditions governing feasible pressures of forging. Using height-to-diameter or height-to-width as measure of this, there are minimum limits below which flow pressures rise prohibitively.

In summary, a potential process is available by which the cost and isotropy of mechanical property characteristics of castings can be combined with properties approaching those of forgings.

ACKNOWLEDGMENT

This development program was supported by the Manufacturing Methods Branch of the Air Materiel Command of the Wright-Patterson Air Force Base under Contract No. AF 33(600)-30159. Sponsorship and permission to publish are gratefully acknowledged by the authors. The constructive advice of A. Langenheim of the sponsoring agency has been of considerable value to the progress of the work.

CONTENTS

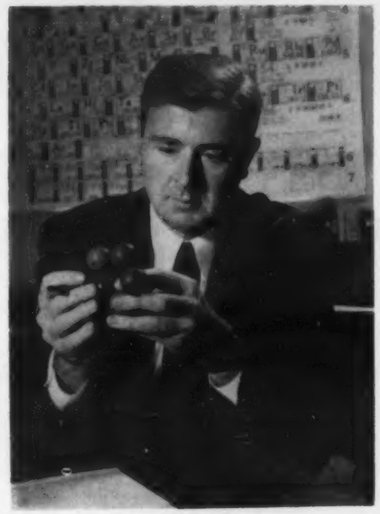
Man's Role in Rocket-Atomic Age to be Outlined by Scientist at Banquet

An outstanding authority on atomic energy, Dr. Ralph E. Lapp will be the speaker at the Annual AFS Banquet to be held on Wednesday evening, May 21, at Cleveland. His subject will be *"Men, Rockets, and Atoms."*

Dr. Lapp earned his doctorate in cosmic ray physics at the University of Chicago under Dr. Arthur H. Compton. He began his professional scientific work with the late Dr. A. J. Dempster, discoverer of U-235. Later he was associated with Dr. Vannevar Bush and Dr. J. Robert Oppenheimer.

He served as division director of the wartime Manhattan Project and during the postwar years was assistant director of the Argonne National Laboratory until appointed scientific adviser to the War Department General Staff. In 1947 he was made executive director of the Research and Development Board and in 1948 became head of the Nuclear Physics Branch of the Office of Naval Research. He also led the scientific group at both A-Bomb tests at Bikini.

After leaving the government service he established his own scientific consulting service, has given numerous lectures and authored several books. His most recent activity has been extensive studies on radiation fallout in Japan.



Dr. Ralph Lapp

Dr. Lapp in 1957 appeared as speaker at the AFS Wisconsin Regional Foundry Conference and the Chapter Officers Conference.

Deadline Drawing Near for AFS 1958 Kennedy Memorial Apprentice Contest

Less than six weeks remain in the 1958 AFS Robert E. Kennedy Memorial Apprentice Contest. All entries to be considered for national judging must be received prior to 5:00 pm, April 7, at the University of Illinois, Navy Pier, Chicago. Entries must be addressed to the attention of Prof. R. W. Schroeder.

Chapters conducting apprentice contests are reminded that local judging will have to be completed not later than the middle of March in order to allow for transportation to Chicago.

The contest is attracting increased participation in all five divisions and it appears that the 1958 contest will be one of the largest ever with the number of contestants almost equalling the final totals for the 1957 contest.

Cash prizes have been increased to $100, $75, and $50 for the 1st, 2d, and 3rd place winners in each division. In addition the contest for the first time provides first class pullman transportation to and from the convention city for the 1st and 2d place winners of each division.

Competition is held in five divisions; wood patternmaking, metal patternmaking, iron molding, steel molding, and non-ferrous molding.

Eligibility

Any apprentice, learner, or trainee in the foundry industry who has not had more than five years patternmaking experience, nor more than four years molding experience is eligible to enter the contest. Membership in the American Foundrymen's Society, either by the contestant or his employing company is not required. The amount of apprentice training completed has no bearing on eligibility and is not considered in the judging.

Where an AFS chapter holds a local elimination contest, any and all entries from plants located in that chapter's territory must clear through

continued on page 106

National News

Participation of New Divisions Broadens 62d Congress Program

Participation by the Society's two new technical divisions in the 62d Castings Congress has bolstered the 1958 Congress program. Final arrangements are now being made for the inclusion of the Ductile Iron Division and the Die Casting & Permanent Mold Division.

The Ductile Iron Division will be active in one of the sessions conducted by the Gray Iron Division and the Die Casting & Permanent Mold Division will co-sponsor a luncheon with the Light Metals Division.

Approximately 100 technical papers are expected to be presented at the Convention. The program and papers committee of the various divisions are now in the process of approving the papers. Those submitted prior to Jan. 15 will be preprinted in MODERN CASTINGS before the Congress.

Papers approved to date represent seven of the Society's divisions. Subjects include design, melting, the CO_2 process, shell molding, and several papers dealing with sand.

Those preprinted to date include:

"*A Literature Review of Metal Penetration*," A. E. Murton and S. L. Gertsman, Department of Mines and Technical Surveys, Ottawa, Ontario, Canada.

"*Hot Deformation of Sand*," H. W. Dietert, Harry W. Dietert Co., Detroit, and Tom E. Barlow, Eastern Clay Products Dept., International Minerals & Chemical Corp., Chicago.

"*Hardenability of Pearlite Malleable Iron*," report of AFS Pearlitic Malleable Committee.

"*Improving Electric Furnace Refractory Life by Special Shell Cooling Techniques*," Vernon J. Howard, Oklahoma Steel Castings Co., Div. American Steel & Pump Corp., Tulsa, Okla.

"*Theoretical Concepts of Packing Small Particles*," J. B. Caine, consultant, Cincinnati, and C. E. McQuiston, Advance Foundry Co., Dayton, Ohio.

"*Observations on Pinhole Defects in White Iron Castings*," R. W. Heine, University of Wisconsin, Madison, Wis.

"*Density of Sand Grain Fractions of the AFS Sieve Analysis*," R. W. Heine, and T. W. Seaton, America Silica Sand Co., Ottawa, Ill.

"*Gases in Cast Iron with Special Reference to Pickup of Hydrogen from Sand Molds*," J. V. Dawson and L. W. L. Smith, British Cast Iron Research Association, Birmingham, England.

One of the papers to be presented by the Ductile Iron Division is "*Some Structural Considerations in Nodular Iron*," by Verne Pulsifer, Armour Research Foundation, Illinois, Institute of Technology, Chicago.

The Gray Iron Division has approved "*Risering of Gray Iron Castings*," by J. F. Wallace, and E. V. Evans, Case Institute of Technology, Cleveland.

Approval has been given by the Steel Division to "*Purchase Specifications for Commonly Used Steel Foundry Mold and Core Sand Binders*," by Edward G. Vogel, Lebanon Steel Foundry, Lebanon, Pa.

Among the papers approved by the Sand Division are:

"*Mold Surface Behavior*," Dan Roberts, Oil City Iron Works, Corsicana, Tex., and Earl E. Woodliff, foundry sand engineer, Detroit.

"*Deoxidation Practice for Copper Shell-Molded Castings*," R. C. Harris, Pittman-Dunn Laboratories, Frankford Arsenal, Philadelphia.

"*Correlation of Green Strength, Dry Strength and Mold Hardness of Molding Sands*," R. W. Heine; E. H. King and J. S. Schumacher, Hill & Griffith Co., Cincinnati.

"*Investigation of the Hardening of Sodium Silicate Bonded Sand*," Carl E. Wulff, University of Wisconsin, Madison, Wisc.

"*Evaluation of Shell Molding Process Capability*," W. C. Truckmiller, C. R. Baker, and G. H. Bascom, Albion Malleable Iron Co., Albion, Mich.

Tentative Program 62d Castings Congress
American Foundrymen's Society
Cleveland, May 19-23, 1958

MONDAY, MAY 19

7:30 am . . . Author-Chairman Breakfast

8:00 am . . . Registration Opens
Exhibits open 8:30 am–5:30 pm

9:00 am . . . Technical Sessions: Pattern; Steel; Malleable (9:30 am)

12:00 noon . . . Round Table Luncheon: Steel

2:30 pm . . . Technical Sessions: Sand; Pattern; Malleable

4:00 pm . . . Technical Sessions: Fundamental Papers; Sand

8:00 pm . . . Malleable Shop Course

TUESDAY, MAY 20

7:30 am . . . Author-Chairman Breakfast

8:00 am . . . Registration Opens

9:00 am . . . Technical Sessions: Pattern; Light Metals; Safety, Hygiene & Air Pollution; Steel
Exhibits open 9:00 am–5:30 pm

12:00 noon . . . Round Table Luncheons: Malleable; Pattern

2:30 pm . . . Technical Sessions: Fundamental Papers; Light Metals; Sand

4:00 pm . . . Malleable Shop Course

6:00 pm . . . Canadian Dinner; Sand Division Dinner

8:00 pm . . . Sand Shop Course

WEDNESDAY, MAY 21

7:30 am . . . Author-Chairman Breakfast

8:00 am . . . Registration Opens

9:00 am . . . Annual Business Meeting and Annual Hoyt Lecture
Exhibits open 11:30 am–5:30 pm

12:00 noon . . . Management Luncheon

2:30 pm . . . Technical Sessions: Education; Light Metals; Gray Iron; Sand

4:00 pm . . . Technical Sessions: Plant & Plant Equipment

7:00 pm . . . Annual AFS Banquet

THURSDAY, MAY 22

7:30 am . . . Author-Chairman Breakfast

8:00 am . . . Registration Opens

9:00 am . . . Technical Sessions: Brass & Bronze; Gray Iron; Heat Transfer
Exhibits open 9:00 am–5:30 pm

12:00 noon . . . Round Table Luncheon: Light Metals

2:30 pm . . . Technical Sessions: Brass & Bronze; Industrial Engineering; Sand

4:00 pm . . . Technical Session: Light Metals

7:00 pm . . . AFS Alumni Dinner

8:00 pm . . . Gray Iron Shop Course

FRIDAY, MAY 23

7:30 am . . . Author-Chairman Breakfast

8:00 am . . . Registration Opens

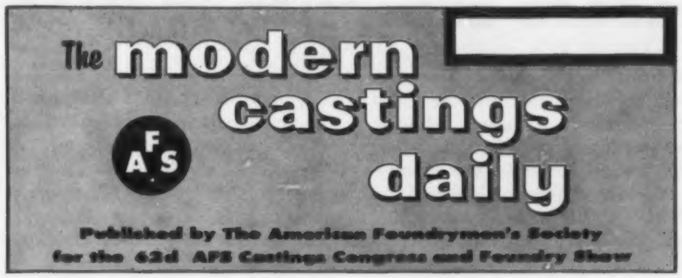
9:00 am . . . Technical Sessions: Brass & Bronze; Gray Iron; Heat Transfer
Exhibits open 9:00 am–5:30 pm

12:00 noon . . . Round Table Luncheons: Gray Iron; Brass & Bronze

2:30 pm . . . Technical Sessions: Brass & Bronze; Industrial Engineering; Sand; Gray Iron Shop Course

Final arrangements have not been made for the participation of the Die Casting & Permanent Mold Division or the Ductile Iron Division. Both will participate in the 62d Castings Congress.

Announcing:



to Cover Convention

Daily coverage of the AFS Convention will be provided for the first time at the Cleveland Convention through the MODERN CASTINGS DAILY. The tabloid-sized newspaper will be printed overnight in Cleveland and distributed free daily at the Convention.

The DAILY will provide day-to-day reporting of Convention-Exhibit activities and contain highlights to assist visitors in planning their activities.

Included in the reporting of the Exhibition will be a daily attendance list, spot photographs, pictures of outstanding exhibits, and convention personalities.

Listing of the official program and the day's activities, abstracts of technical papers, and pictures of the technical sessions, luncheons, dinners and shop courses will be included in each issue.

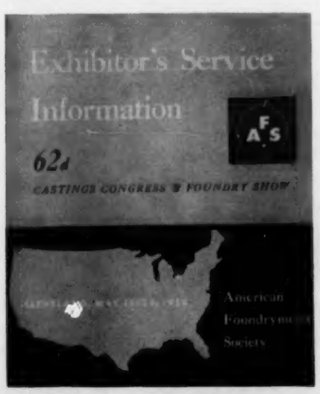
In addition to reporting AFS events at the Convention, the DAILY will also outline the general program of the Society including progress of the Training & Research Institute.

Advertising will be accepted in the DAILY. Because the percentage of advertising is strictly limited, space reservations will be accepted in the order received.

Advertising is available only to exhibitors in standard 7x10 in. page size, black and white.

Exhibitors Booklet Tells How to Avoid Delays and Obtain Best Results at Show

Exhibitors Service Information booklets have been mailed to all the companies participating in the Foundry Show to be held at the Cleveland Public Auditorium, May 19-23.



The 39-p. publication contains complete information regarding rules and regulations and necessary forms for the official directory of exhibits, classified guide to exhibited products and services, advance registration, booth signs, standard booth equipment, housing applications, application for advertising in MODERN CASTINGS DAILY and MODERN CASTINGS, and various official services.

Ten steps are suggested to avoid delays and to obtain the maximum benefit from the exhibitions. Among the recommendations are promptness in completing service forms and returning them to AFS Headquarters at Des Plaines, Ill. All exhibitors are reminded that advance planning and a thorough understanding of rules and regulations will minimize misunderstandings and last-minute problems.

Rules and regulations for the 1958 Foundry Show have been formulated and agreed to by the AFS Committee of Exhibitors composed of executives representing companies exhibiting at the Foundry Shows sponsored by AFS. Members of the 1958 Committee are:

AFS President Harry W. Dietert, Chairman.
J. G. Bair, Fox Grinders, Inc., Pittsburgh, Pa.
T. E. Barlow, International Minerals & Chemical Corp., Chicago.
Warner B. Bishop, Archer-Daniels-Midland Co., Cleveland.
E. F. Brissie, Doehler-Jarvis Div., National Lead Co., New York.
W. W. Brown, Superior Foundry, Inc., Cleveland.
W. J. Cluff, Frederic B. Stevens, Inc. Detroit.
R. W. Fross, A. P. Green Fire Brick Co., Mexico, Mo.
L. H. Heyl, Archer-Daniels-Midland Co., Federal Foundry Supply Div., Cleveland.
Jack Lorenzen, Mueller Industries, Inc., Aurora, Ill.
C. V. Nass, Beardsley & Piper Div., Pettibone Mulliken Corp., Chicago.
Dan Oliver, Howard Foundry Co., Chicago.
E. A. Rich, Wheelabrator Corp., Mishawaka, Ind.
F. L. Robertson, Keokuk Steel Castings Co., Keokuk, Iowa.
C. A. Sanders, American Colloid Co., Chicago.
G. E. Seavoy, Whiting Corp., Harvey, Ill.
D. G. Stewart, Union Carbide Corp., New York.
V. F. Stine, Pangborn Corp., Hagerstown, Md.
R. H. Sutter, Sutter Products Co., Dearborn, Mich.
T. H. Tanner, Zenith Foundry Co., Milwaukee.
Wm. W. Maloney, AFS General Manager.
W. N. Davis, AFS Exhibit Manager.

Northeastern Ohio Day Committee is Announced

■ Members of the Northeastern Ohio Day committee have been announced by Emil J. Romans, General Convention Committees Chairman. One day at each Convention is set aside to allow foundry employees in the host chapter's area an opportunity to attend the Convention with no admission charge.

This provides foundrymen in the area an opportunity to observe the latest in new equipment and machinery as well as casting techniques.

Northeastern Ohio Day will be held Friday, May 22, between 9:00 am-5:00 pm.

Committee members will be responsible for circulating "free day" passes to foundries in the Cleveland area for the admission of their employees to the 62d Castings Congress & Foundry Show.

Chairman, Norman J. Stickney, Sand Products Corp.
F. W. Boehmer, James H. Herron Co.
Edward R. Brennan, Forest City Foundries, Inc.
E. R. Crosby, Smith Facing & Supply Co.
Fred S. Green, Elyria Foundry Div., Industrial Brown Hoist Co.
Richard A. Green, Eastern Clay Products Dept., International Minerals & Chemicals Corp.
Donald C. Hartman, Cover Pattern Works.
Robert H. Herrmann, Penton Publishing Co.
Howard E. Heyl, Federal Foundry Supply Co.
Charles J. Jelinek, Ford Motor Co., Cleveland Foundry.
W. O. Larson, Jr., W. O. Larson Foundry Co.
Lawrence R. Lansky, Superior Foundry, Inc.
George Luekens, Hickman, Williams & Co.
E. A. Macke, Jr., Republic Steel Corp.
Wm. E. Mahoney, Madison Foundry Co.
George Nestor, Jr., National Malleable & Steel Castings Co.

N. J. Stickney

Robert W. Newyear, Taylor & Boggis Foundry Co.
Gordon L. Paul, Sterling Foundry Co.
Charles D. Pinkerton, George F. Pettinos, Inc.
Lawrence E. Rayel, Archer-Daniels-Midland Co.
J. Doyle Robbins, Osborn Mfg. Co.
Ernest F. Thomas, Ohio Foundry Co.
James J. Schwalm, Federal Foundry Supply Co.
John E. Sibbison, Jr., Kerchner Marshall Co.
Walter H. Siebert, Cleveland Standard Pattern Works.
John F. Wallace, Case Institute of Technology.
Harold Wheeler, Allyne-Ryan Foundry Co.

Apprentice Contest

Continued from page 103

the local chapter elimination contest. The 1st, 2d, and 3d place winners of the local chapter elimination contest in each division may be submitted to the national judging, giving a possible total of 15 national entries from any one chapter contest.

Apprentice

In the event no local chapter contest is held, only the 1st place entry in each division may be entered in the national judging from a single plant.

Judging

Judging will be conducted on a point-score basis. Three different score cards will be used; one for wood patternmaking, one for metal patternmaking, and a third for iron, steel, and non-ferrous molding. In each division a maximum of 100 points will be awarded. Following are the official score cards.

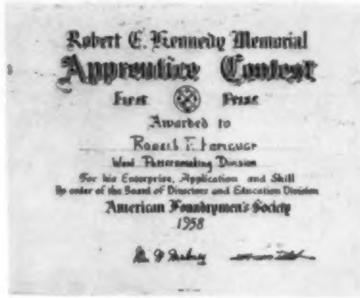
Wood Patternmaking	
Accuracy According to Drawing	35 max.
Moldability	35 max.
Workmanship	20 max.
Time	10 max.
Total	100 max.
Metal Patternmaking	
Accuracy According to Drawing	50 max.
Workmanship	30 max.
Time	20 max.
Total	100 max.
Iron, Steel, Non-Ferrous Molding	
Gates & Risers	20 max.
Yield	10 max.
Cleanability	10 max.
General Appearance	20 max.
Soundness	25 max.
Time	15 max.
Total	100 max.

Sixteen AFS chapters are conducting local elimination contests in the 1958 Robert E. Kennedy Memorial Apprentice Contest. Two Canadian chapters are participating as well as chapters from most sections of the United States. The chapters are:

- Canton District, Central Ohio
- Corn Belt
- Detroit
- Eastern Canada
- Michiana
- Northeastern Ohio
- Northern Illinois-Southern Wisconsin
- Ontario
- Oregon
- Philadelphia
- Quad City
- St. Louis District
- Southern California
- Washington
- Wisconsin

Contest Regulations

All castings entered in the molding divisions must be made in green sand molds only. If baked cores are needed, it is not required that they be made by the contestant. Castings must be blasted, and shall not be coated, ground, chipped, or welded. Risers and gates shall not be removed.



Molding time shall commence when the contestant personally receives the pattern, and shall include all planning and study, closing the mold, and clamping or weighting ready for pouring.

Pattern entries shall be coated only as specified on the blueprint. Standard pattern colors shall not be used. Patternmaking time shall commence when the contestant personally receives the blueprint, and shall include all planning and study. Shellac must be applied, but may still be wet when the contestant relinquishes his pattern.

Molding patterns and blueprints for the required pattern divisions shall be supplied to contestants by the AFS Central Office in Des Plaines, Ill., or by the local chapter contest committee. All other equipment and supplies shall be furnished by the contestant or his shop.

Contest identification tags will be furnished by the Central Office or local contest committee. Only the following data shall be entered on entry tags; contestants' registry number assigned by AFS, time consumed in completing entry. With casting entries only, gross weight and approximate metal analysis. Personal or company names must not be identified on tags or entries. This will disqualify the entry.

Successful entries from local chapter contests or individual plant contests must be shipped only to Prof. R. W. Schroeder, University of Illinois, Pier 47, Navy Pier, Chicago, Ill. Transportation charges on all national contest entries shall be prepaid.

Acceptance of T&RI Program Leads to Expansion in 1958

Activities for the T&RI 1958 program are now entering the third month. Courses on Cupola Melting of Iron were presented Jan. 27-31 in Chicago and Feb. 10-12 at Oakland, Calif., the latter being sponsored by the Northern California Chapter.

During March a course on Non-Destructive Testing will be given in Chicago; and March 16-18 the Ontario Chapter will sponsor the Cupola Melting of Iron course at Hamilton, Ontario.

Other courses to be given during 1958 include Melting of Copper-Base Alloys, Metallography of Ferrous Metals, Sand Testing, Metallography of Non-Ferrous Metals, Sand Lecture Course, Patternmaking, Industrial Development, Product Development, Air Pollution Control and Legislation, Industrial Engineering, Gating and Risering of Ferrous Castings, and Foundry Plant Layout.

As a result of the reception by industry the 1958 T&RI program has been expanded considerably. One of the most important features is the presentation of courses under the sponsorship of local chapters. This is one of the objectives outlined when plans for the T&RI were formulated.

Basically three phases of foundry operations were covered during 1957. These were sand, industrial engineering and cupola melting of iron. The selection of the 1958 courses were made in response to requests by industry and the students.

Reservations are now open. Make reservations by course numbers and date. Registrants will be accepted in order received until enrollment is filled. Payment of tuition fees should accompany enrollment application.

Make reservations with Director, AFS Training & Research Institute, Golf & Wolf Roads, Des Plaines, Ill.

Attending **Cupola Melting of Iron Course** in Chicago, Jan. 27-31, were Ken Detert, Brillion Iron Works, Brillion, Wis.; John Barilich, Sibley Machine & Foundry Co., South Bend, Ind.; E. Skelly, American-Standard Products Ltd., Toronto, Ontario, Canada; J. C. Maloney, Chris. Erhart Foundry & Machine Co., Cincinnati; and Robert Jones, Posey Iron Works, Lancaster, Pa.

Tentative Schedule of 1958 T&RI Courses

Date	Subject	Location	Fee	Course No.
March 3-7	Non-Destructive Testing	Chicago	$100	T2A-58
March 16-18	Cupola Melting of Iron	Hamilton, Ontario	30	M3C-58
April 2-4	Melting of Copper-Base Alloys	Chicago	40	M2A-58
April 16-18	Metallography of Ferrous Metals	Chicago	40	MTY1A-58
June 2-6	Sand Testing	Detroit	125	SIA-58
June 25-27	Metallography of Non-Ferrous Metals	Chicago	40	MTY2A-58
July 7-11	Cupola Melting of Iron	Chicago	65	M3D-58
Aug. 4-8	Sand Lecture Course	Detroit	65	S23A-58
Aug. 18-20	Patternmaking	Chicago	40	PM1A-58
Sept. 8-12	Industrial Environment	Chicago	65	SAF1A-58
Sept. 24-26	Product Development	Chicago	40	PD1A-58
Oct. 1-3	Air Pollution and Legislation	Chicago	40	SAF2A-58
Oct. 13-17	Industrial Engineering	Chicago	125	IE1A-58
Oct. 27-31	Gating and Risering of Ferrous Castings	Chicago	65	GR1A-58
Nov. 10-12	Foundry Plant Layout	Chicago	40	IE2A-58

Sponsored Research Projects

Malleable Program Started at Wisconsin

Investigation to determine the commercial possibilities of producing malleable iron castings up to 6-in. thick is now being conducted at the University of Wisconsin, Madison, Wis. This is the latest AFS Training & Research Institute-sponsored research project to provide basic information for improving casting quality and broadening the applications. Work on this project was started in January.

Members of the committee are:
Chairman Carl Joseph, Central Foundry Div., General Motors Corp., Saginaw, Mich.
Vice-Chairman W. D. McMillan, International Harvester Co., Chicago.
Hyman Bornstein, retired.
J. H. Lansing, Malleable Founders' Society, Cleveland.
Milton Tilley, National Malleable & Steel Castings Co., Cleveland.
P. F. Ulmer, Link-Belt Co., Indianapolis.
R. V. Osborne, Lakeside Malleable Castings Co., Racine, Wis.
R. P. Schauss, Werner G. Smith, Inc., Chicago.
Richard Schneidewind, University of Michigan, Ann Arbor, Mich.

Five Other Investigations Also Underway

Five other research projects are currently being conducted under T&RI sponsorship or auspices.

Investigation of the pressure tightness of 85-5-5-5 leaded red brass castings is being conducted at the University of Michigan, Ann Arbor, Mich.

The program is attempting to isolate and evaluate the variables leading to leakage under pressure and to develop quantitative data relating pressure tightness to mold characteristics and metal quality.

A study of gating and risering is being conducted at Case Institute of Technology, Cleveland. Following a review of data from many sources, an attempt will be made to evolve an ideal gating and risering technique which would be universally applicable, with modifications, to all types of cast metals.

Work is underway at the sand testing laboratory of Locomotive Finished Material Div., Rockwell Mfg. Co., Atchison, Kans., to study physical properties of steel foundry sands at elevated temperatures.

Physical properties of iron foundry molding material at elevated temperatures is being studied at the University of Wisconsin. Preliminary work has been completed dealing with veining.

The fifth project is a thermodynamics study of castings at Battelle Memorial Institute, Columbus, Ohio. This is financially supported by the Army Ordnance Corps with the Light metals Research Committee acting as an advisory group.

Offer Free Case and Rack with Books

A complete set of current AFS publications, plus a storage case and display rack are being offered to all chapters for $150, the member price for the publications alone. The storage case measures 12x13½x22 in. and contains a collapsible book rack.

As a means of obtaining additional funds, chapters are allowed a 20 per cent discount from the member price on orders which originate from a chapter book salesman. The complete set of books attractively displayed in the book rack at meetings should spark sales.

"Authoritative information such as contained in AFS publications is only of value if the membership avail themselves of the books," AFS Technical Director S. C. Massari points out. "The storage case is designed so that the unit can be stored from one meeting to the next without any difficulty, and the rack makes a convenient display of the available publications," he added.

The sale of AFS publications by certain chapters has been good. However, all chapters could increase distribution of the publications by appointing a book sales committee which would display available books at each chapter meeting. A profit of $30 will be returned to each chapter merely by the selling of a single copy of each of the AFS publications.

Orders are still being accepted at AFS Headquarters, Des Plaines, Ill. for the publications and free storage case and book rack.

The following publications are included with the case and rack. AFS member price is shown opposite each book:

General Foundry Interest

Analysis of Casting Defects	1.50
Bibliography of Centrifugal Casting	1.50
Cast Metals Handbook	7.00
Development of Metal Castings Industry	3.00
Foundry Core Practice	6.50
Foundry Sand Handbook	3.50
Glossary of Foundry Terms	.75
Permanent Mold Castings Bibliography	1.50
Processing Molding Sands	1.50
Recommended Names for Gates & Risers (Booklet)	.25
Statistical Quality Control for Foundries	4.50
Symposium on Molding Machines	$1.00
Symposium on Non-Destructive Testing	1.00
Symposium on Principles of Gating	2.00
Symposium on Sand Reclamation	1.50
Time and Motion Study for the Foundry	5.50

Patternmaking

Patternmaker's Manual	4.50
Pattern Standard Color Chart	.25

Safety, Hygiene and Air Pollution Control

Control of Emissions from Metal Melting Operations	1.50
Engineering Manual for Control of In-Plant Environment in Foundries	6.00
Foundry Air Pollution Manual	4.25
Good Practices for Metal Cleaning Sanitation	1.25
Grinding, Polishing and Buffing Equipment Sanitation	.75
Health Protection in Foundry Practice	3.00
Recommended Safety Practices for the Protection of Workers in Foundries	2.00
Symposium on Foundry Safety, Health and Air Pollution	3.00
Safe Practices Manual for Welding, Cutting, Brazing, Soldering and Similar Operations	3.00

Training and Education

Apprentice Training Standards for the Foundry Industry	1.00
Foundry Work	1.96
Guide for Foreman Training Conference	1.50
Principles of Metal Casting	7.50

Foundry Costs

Advanced Cost Accounting Method for Gray Iron Foundries—No. 2	10.00
Basic Cost Principles for Non-ferrous Foundries	5.00
Classification of Foundry Cost Factors	1.00

Transactions

Volume 65—1957	10.00
Index to AFS Transactions (1941-1950)	2.75

Ferrous Foundry Practice

Alloy Cast Irons Handbook	$2.75
American Malleable Iron Handbook (MFS)	4.00
The Cupola and its Operation	6.00
Engineering Properties of Cast Iron	2.25

Ferrous Foundry Process Control (SAE)	1.50
Recommended Names for Gates and Risers (Booklet)	.25
Annotated Bibliography of Cupola Operations	2.00

Charts

Graphite Classification Chart (25x38 in.)	1.25
Recommended Names for Gates and Risers (17x28 in.)	.25

Research Reports

Risering of Gray Iron Castings—Report No. 2	1.00
Risering of Gray Iron Castings—Report No. 4	.35
Risering of Gray Iron Castings—Report No. 5	.35
Steel Sands at Elevated Temperatures (No. 12)	.40

Non-Ferrous Foundry Practice

Cast Bronze (ASM)	6.00
Copper-Base Alloys Foundry Practice	3.75
Design of Die Castings	5.25
Modifications in Vertical-Gating Principles	.50

Research Reports

Melt Quality and Pressure Tightness of Copper-Base Alloys	1.00
Principles of Gating as Applied to Sprue-Base Design	.50
Principles Applicable to Vertical Gating	.50
The Study of Vertical Gating	.50

Committees in Action

Noise Control Committee meeting in Chicago Jan. 21 approved the Foundry Noise Exposures Chapter and engineering terms for the glossary of Foundry Noise Control Manual. The glossary contains 45 definitions. Shown in photo, seated, are: H. J. Weber, AFS Director of Safety, Hygiene & Air Pollution; Chairman H. T. Walworth, Lumberman's Mutual Casualty Co., Chicago; Dr. E. G. Meiter, Employers Mutual Liability Inc. Co. of Wisconsin, Milwaukee; W. T. McCormick, Inland Steel Co., East Chicago, Ind. Standing, F. E. Frazier, National Association Mutual Casualty Co., Chicago; J. W. Lake, Michigan Mutual Liability Co., Detroit; Vice-Chairman J. C. Radcliffe, Ford Motor Co., Dearborn, Mich.

Brass & Bronze Division

■ Participants have been announced for the Division's Round Table Luncheon and Shop Course to be held at the 1958 Castings Congress in Cleveland.

"New Developments in Copper-Base Alloy Casting Methods" has been selected as the subject of the panel discussion to be held at 12 noon, Friday, May 23. Topics and panelists are:

Sand—L. J. Pedicini, Birmingham, Mich.

Permanent Molding, Norman Birch, American Brake Shoe Co., St. Louis.

Centrifugal Casting, Nathan Janco, Centrifugal Casting Co., Tulsa, Okla.

A panel discussion on *"What is Expected of a Casting"* will be conducted as the Shop Course Program. Topics and participants are:

"Casting Redesign," W. F. Straight, Bethlehem Steel Co., Quincy, Mass.

"Casting Design," J.S. McVey, General Electric Co., Everett, Mass.

"Casting Purchase," J. W. Foster, Ingersoll-Rand Co., Phillipsburg, N. J.

Sand Division

■ Fourteen possible factors in controlling casting surface finish have been listed by the Mold Surface Committee which is seeking means of improving casting smoothness.

ADVERSE FACTORS are:
- Metal that is too hot.
- Oversized sand grains.
- Excessive sand fines.
- Sands with sharp peak fineness curves.
- Soft ramming.
- Over-ramming.

BENEFICIAL PRACTICES use:
- Metal head pressure at a minimum.
- Finest sand permissible.
- Adequate squeeze pressure.
- Facing sand additives.
- Sand with good flowability.
- Good pattern equipment.
- Control sand moisture in narrow range.
- Mold washes.

Members of the Phillipine productivity team shown with AFS Staff members at Jan. 24 meeting. Left to right are A. B. Sinnett, AFS Assistant Secretary; Tomos L. Parpana, Parpana Machinery Mfg., Inc., Manila; Justine P. Yaptangco, Mechanical Center, Manila; Leslie A. White, International Cooperation Administration, Washington, D. C.; S. C. Massari, AFS Technical Director; Wm. W. Maloney, AFS General Manager; Catalino O. Luciano, Pacific Engineering Co., Manila; Santos B. Barros, Bataan National Shipyards, Bataan; Casto L. Cosme, National Shipyards & Steel Corp., Manila; Maximo M. Mercado, Machinery, Assembly & Machine Shop, Atlantic, Gulf & Pacific Co., Manila; and Ireno D. Obligacion, Oriental Machineries, Manila.

Chapter News

Ontario Chapter in Cooperation with T&RI Presents Course on Cupola Iron Melting

■ Hamilton, Ontario, Canada, will be the site of the first AFS Training & Research Institute program presented outside of the United States. The two-day course will be given by the T&RI in cooperation with the AFS Ontario Chapter.

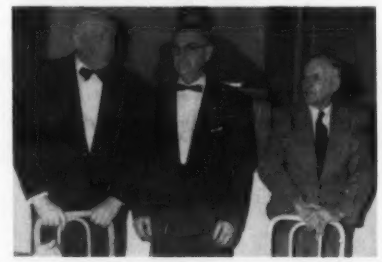
Originally the course was conceived by the education committee of the Ontario Chapter. Subsequently the development and presentation of the program was turned over to the T&RI. AFS National Director Alex Pirrie and Officers and Directors of the Chapter were largely responsible for the Ontario Chapter being the first to cooperate with the Institute in the presentation of a foundry educational program.

The course, Cupola Melting of Iron, will be given March 17-18 at the Royal Connaught Hotel, Hamilton. Instructors for the course are: E. J. Burke, Hanna Furnace Corp., Buffalo, N. Y.; Howard Wilder, Vanadium Corp. of America, Chicago; and S. C. Massari, Director, AFS Institute.

Ten major subjects comprise the course. These are:
- Cupola Design & Construction.
- Raw Materials Purchasing
- Coke
- Preparation & Operation
- Essential Records
- Desulphurization
- Combustion Control
- Temperature Measurement
- Metallurgy of Cast Iron
- Operating Problems

The registration forms have been mailed to all members of the Ontario, Eastern Canada, Rochester, Western New York, and Central New York Chapters. Registrations must be received before March 1. All applications are to be mailed to Director, AFS Training & Research Institute, Golf & Wolf Roads, Des Plaines, Ill.

All persons enrolled in the course will be evaluated in terms of individual achievement. A report of certification and evaluation will be sent each registrant's superior for analysis and up-grading purposes.



Four, 50-year foundrymen were honored at the December meeting of the **Ontario Chapter.** Left to right are George Stewart, who started with Canadian Westinghouse Ltd., Hamilton, Ontario, in 1907, and is now patternshop foreman. Clarence Dulcan, now retired from National Iron Division, Canada Iron Foundries Ltd., Toronto, Ontario, who also entered the foundry line in 1907; and Walter Price, retired from Welland Iron & Brass Works, Welland, Ontario, who started in the foundry line in 1902. Not shown is J. J. Dillon, who has been with Galt Malleable Co., Galt, Ontario, for 51 years and is now plant superintendent.

Central Indiana Chapter held a past chairmen's night during January at Indianapolis. Left to right are Carl O. Schopp, Link-Belt Co., Indianapolis; Fred E. Kurtz, Electric Steel Castings Co., Indianapolis; James A. Barrett, National Malleable Steel Casting Co., Indianapolis; J. P. Lentz, International Harvester Co., Indianapolis; R. H. Brookes, Link-Belt Co., Indianapolis; William M. Fitzsimmons, International Harvester Co., Indianapolis, present Chapter Chairman; Allen J. Reid, General Refractories Co., Indianapolis; Robert Langsenkamp, Langsenkamp-Wheeler Brass Works, Indianapolis; and Dallas Lunsford, Perfect Circle Corp., New Castle, Ind. Past chairmen's night is an annual chapter event.—*William R. Patrick*

Southern California

Feature Local Speakers

■ Technical sessions in December and January for the Southern California Chapter featured local foundrymen. A castings clinic was held in December followed by a discussion of *"Making Cores by the Air Set Process"* in January.

More than 140 members attended the casting clinic featuring three panelists. Ray Relph, Hanford Foundry, discussed problems of the steel foundrymen; Rick Dolan, Dayton Foundry, handled the iron discussion; and C. J. Egetter, Crown Brass Mfg. Co., represented non-ferrous shops. Meetings were held in the Rodger Young Auditorium, Los Angeles.

The clinic is an annual activity of the chapter. The meeting is thrown open to discussion following comments from the panelists and has become one of the most popular meetings.

Ray Silva, Fairbanks, Morse & Co., presented an illustrated lecture on the air set process in January to more than 175 foundrymen. Advantages of the process were listed as:

Minimum or elimination of ramming
Minimum of venting
Reduction of venting
More accurate cores
Less core sagging
Cleaner castings
Reduction of baking time—*H. E. Simmons*

Three brother foundrymen, Ray and Frank Silva of Fairbanks, Morse & Co., and John Silva, Warren Foundry.

Attending the January meeting were William Mitchell, Utility Steel Foundry; speaker Ray Silva; Chapter Vice-Chairman Otto Rosentreter, Rosentreter Co.; and standing, Leonard Hofstetter, Brumley-Donaldson Co.—*Ken Sheckler*

Group at December castings clinic.

Northeastern Ohio Chapter

Study Quality Control

■ Foundrymen and members of the American Society for Quality Control, Cleveland section, held a joint meeting Jan. 9 discussing quality control. Dr. Kenneth Bock, National Malleable & Steel Castings Co., Cleveland, talked on *"Quality Control is Old Stuff,"* prior to a panel discussion on the same subject.

Dr. Bock emphasized that there is nothing new about quality control and stated that satisfactory results can be obtained from the simplest of programs if immediate action is taken. He stated that one of the most important assets of a quality control program is the speed with which corrective action can be taken when a change of quality is indicated.

Following the talk, a panel discussion was held on quality control. Participating were Thomas R. Gauthier, Aluminum Co. of America; Arnold L. Robertson, Superior Foundry, Inc.; Donald Leckie, Republic Steel Corp.; and W. H. Williams, Eaton Mfg. Co., all of Cleveland.

It was agreed that the human element is the most difficult factor to control. Better trained personnel was pointed out as one way of improving quality control programs.

Karl G. Presser, Forest City Foundries Co., Cleveland, served as technical chairman. More than 250 persons attended the joint meeting.—*Kenneth L. Mountain*

Mo-Kan Chapter

Patternmaking Opportunities

■ New opportunities for the pattern industry were outlined at the January meeting by M. K. Young, U. S. Gypsum Co., Chicago. Young described a new plastic material hardened by a capillary resin process permitting production of coreboxes and driers capable of use at 425 F. Chairman T. F. Shadwick, Witte Engine Works., Div. Oil Well Supply Co., Kansas City, Mo. presided—*J. T. Schlanker*

Metropolitan Chapter

Simultaneous Sessions

■ Simultaneous sessions at the January meeting allowed the scheduling of three speakers. *"Modern Steel Melting Practice,"* was discussed by F. E. Van Voris, Electro Metallurgical Co., Div. of Union Carbide Co., New York.

The speaker covered the effects of the carbon dioxide boil used to flush out hydrogen and nitrogen, slag control, the best practices in the use of ladles and ferro alloys, the effects of nitrogen on grain refinement, and pin holes in steel castings.

Harold H. Wilder, Vanadium Corp. of America, Chicago, discussed *"Cupola Operation,"* covering melt rates, coke and metal ratios, physical properties, and the effects of various alloying elements on mechanical properties of cast iron.

"Non-Ferrous Melting," by Norman A. Birch, National Bearing Div., American Brake Shoe Co., was an outline of comparative melting rates, capacities, melt losses, melting atmospheres, and types of alloys.—*C. H. Fetzer*

Technical chairman John P. O'Neil and speaker Wilder.—*John R. Bing*

Left to right, Vice-Chairman W. T. Bourke, Chairman H. E. Voit, speaker Birch and F. E. Van Voris, also a speaker.

Speaker Van Voris shown on left with Robert Fisher who served as chairman.

Washington Chapter members at the January meeting heard William M. Ball, Jr., R. Lavin & Sons, Inc., Chicago, discuss *"Non-Ferrous Practices."* Subjects included molding, melting, metals, and management. Shown in picture left to right are: Director Jack H. Peterson, Peterson Pattern Works, Seattle, Wash.; William Snyder, University of Washington, Seattle, Wash.; Program Chairman Vernon W. Rowe, Ballard Pattern & Brass Foundry, Seattle, Wash.; speaker Ball; and Chapter Chairman William K. Gibb, Atlas Foundry & Machine Co., Tacoma, Wash.—*Jack H. Peterson*

Philadelphia Chapter

Aids to Better Castings

■ Chills, anti-chills, and exothermics as a means of improving casting quality and yields were discussed at the January meeting by Harold Bishop and Michael Bock, II, Exomet, Inc., Conneaut, Ohio. The speakers outlined aids for both ferrous and non-ferrous production. Approximately 115 members attended the meeting held at the Engineers' Club.—*E. C. Klank*

Participating in Philadelphia's January meeting were Chapter Chairman H. C. Winte; speakers Bock and Bishop; and Technical Chairman Robert Mason.

Twin City Meeting in January Includes Visit by AFS Officials

■ Castings defects and their cost to the industry and its customers were presented at the Twin City Chapter in an illustrated lecture at the January meeting by W. A. Hambley, Chas. A. Krause Milling Co., Milwaukee.

Responsibility for correcting these defects must be shared throughout the entire management team. Direct and indirect losses to foundries and customers were also studied.

Chapter directors met prior to the technical session with National Director Allen Slichter, Pelton Steel Casting Co., Milwaukee, and Dan J. Hayes, AFS Field Director.

Those attending (see picture) were R. J. Mulligan, Archer-Daniels-Midland Co.; Fred Junger, Kausel Foundry Co.; J. J. Uppgren, Northern Ordnance, Inc.; Dan J. Hayes; Fred Neal, Smith-Sharpe Co.; Donald Fulton, Northern Malleable Iron Co.; Herbert Jacobson, Gopher Pattern Works; Harry Blumenthal, American Iron & Supply Co.; Fred Quest, J. F. Quest Foundry Co.; Stanley Sitarz, Prospect Foundry Co.; Melvin Schroeder, C. W. Olson Mfg. Co.; Allen Slichter; Mrs. Cloraine O'Crowley, Chapter Secretary-Treasurer; and Frank Ryan, St. Paul Brass Foundry Co.—*J. David Johnson.*

Chapter affairs were discussed prior to the technical meeting by AFS Field Director Dan J. Hayes, left, Chairman J. J. Uppgren, and AFS Director, Allen Slichter, shown on right.

Technical speaker W. A. Hambley, center, is flanked on left by W. A. Hambley, Jr., graduate student at the University of Minnesota, and Chapter Chairman John J. Uppgren, Northern Ordnance, Inc., Minneapolis.

Directors of Twin City Chapter shown at January meeting prior to start of technical session.

Connecticut Chapter Holds First Ladies' Night Program

Despite a 14-in. snow fall, the **Connecticut Chapter's** first Ladies' Night, Jan. 11, attracted a large crowd. Connecticut Non-ferrous Foundrymen Society members and wives also attended. The program included dancing, and entertainment.—*S. J. LeRoy*

Attending the Ladies' Night was this table of Goerge Liff, Mr. and Mrs. Walter Helmadack, Fred Holway, James Baxter, Alexander Beck, Mrs. Egirt, Mr. and Mrs. Henry Stenberg, Mrs. James Baxter, Adolph Egirt, and Mrs. Stephen LeRoy.

New England Chapter

Foundry Mechanization

■ Mechanization in small foundries was the subject of the January meeting. Louis J. Iadarola, Pioneer Foundry Co., Gilbertsville, Mass., traced mechanization at Pioneer Foundry from 1952 until the present. Augustus E. Bouldry, Whitman Foundry, Inc., Whitman, Mass., related the advantages gained at Whitman Foundry through the installation of a new cupola and charging installation.—*F. S. Holway*

Rochester Chapter

Small Foundry Mechanization

■ Statistics on foundry operations in the Rochester area were presented at the January meeting by C. V. Nass, Beardsley & Piper Div., Pettibone Mulliken Corp., Chicago. Nass spoke to the chapter on *"Mechanization in the Small Foundry."* Chapter Chairman A. Murrer, Gleason Works, Rochester, N. Y., presided. Vice-Chairman A. V. Vecchiotti, Antice Co., Rochester, N. Y., served as technical chairman.—*T. B. DeStefani*

Central Ohio Chapter

Holds Winter Party

■ More than 140 persons attended the chapter's winter party held in January at the Lincoln Lodge, Columbus, Ohio.—*Jose Acebo*

Eastern New York

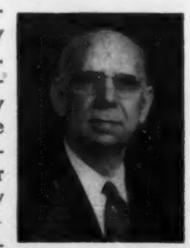
Air Pollution Problems

■ Air pollution problems facing foundries were described at the January meeting by John M. Kane, American Air Filter Co., Louisville, Ky. Ways and means of exhausting dust and fumes were explained and schematic views shown of various systems used on cupolas, reverbatory and carbon arc furnaces. It was pointed out that foundries are frequently unjustly blamed for many local air pollution problems. L. J. DiNuzzo, Chapter Chairman presided. R. N. Williams served as technical chairman.—*Leonard C. Johnson*

Oregon Chapter

Non-Ferrous Practices

■ More than 50 members and guests in January heard William Ball, Jr., R. Lavin & Sons, Inc., Chicago, deliver a talk on copper-base alloy foundry practice. The speaker illustrated bad foundry practices with case histories and pointed out that poor practices not only result in sub-standard castings but also increase manufacturing costs.



The importance of the casting industry was also emphasized and foundrymen were advised that their role will continue to grow in the nation's economy. Mr. Ball pointed out that basic foundry practices are applicable to ferrous as well as non-ferrous production.

Chicago Chapter Offers Coremaking Study in Annual Education Series

■ Four methods of coremaking will be the subject of the Chicago Chapter's annual educational series. The series begins March 3 at the regular chapter meeting. This meeting, known as the kickoff session, will feature *"Why Four Methods of Coremaking,"* by E. C. Zirzow, Werner G. Smith, Inc., Cleveland.

Two other meetings will be held on the following Mondays at the Peoples Gas Light and Coke building. Each meeting will feature two speakers. On March 10 Frank Soderstrom, Continental Foundry & Machine Div., Blaw-Knox Co., East Chicago, Ind., will talk on *"Air Set Cores"* and Robert Greenlee, Auto Specialties Mfg. Co., St. Joseph, Mich., will discuss *"Oil Sand Cores."*

The final program, March 17, will include *"CO_2 Cores"* by George Nestor, National Malleable & Steel Castings Co., Cleveland, and *"Shell Cores"* by J. E. Stock, John Deere Waterloo Tractor Works, Waterloo, Iowa.

The chapter's education committee is headed by L. F. Bartosz, National Mallable & Steel Castings Co., Cicero, Ill. Other members are Raymond E. Kovarik, National Malleable & Steel Castings Co.; Spencer S. Phillips, International Harvester Co.; R. E. Seifert, National Malleable & Steel Castings Co.; and H. G. Haines, Woodruff & Edwards Co. Members of the education committee will serve as technical chairmen at the sessions.

Methods of achieving and maintaining good personnel relations were explained to the **St. Louis Chapter** at its January meeting by Ross C. Shannon, consultant. AFS President Harry W. Dietert met with Chapter Board of Directors on the previous day. Picture shows Technical Chairman John O'Meara, Banner Iron Works, left, congratulating speaker Shannon.—*H. V. Boemer*

"*Research in the Foundry*" was discussed at the **Central Ohio Chapter** December meeting by Dan Krause, Gray Iron Institute, Columbus, Ohio. Krause emphasized that foundry fundamentals should be fully investigated and these facts applied systematically in order to obtain the greatest benefits. Research can also be applied to process development and new products, he stated. Slides were shown demonstrating European advancements. —*Jose Acebo*

The **Tri-State Chapter's** 7th annual Christmas party was held at the Mayo Hotel, Tulsa, Okla., with 232 couples attending. The party committee consisted of B. P. Glover, Carl Oxley, E. F. Hines, T. H. Lahmeyer, and E. W. O'Brien. Shown in picture, left to right: Chapter Secretary W. J. Pitts and Mrs. Pitts; Chapter Treasurer C. B. Oxley and Mrs. Oxley; Chapter Chairman E. W. O'Brien and Mrs. O'Brien; AFS National Director R. W. Trimble and Mrs. Trimble; Christmas Party Chairman B. P. Glover and Mrs. Glover; Chapter Vice-Chairman E. F. Hines and Mrs. Hines; and Chapter Social Chairman T. H. Lahmeyer and Mrs. Lahmeyer.—*Leslie O'Brien*

Core blowing techniques were discussed at the January meeting of the **Eastern Canada Chapter.** Z. Madacey, Beardsley & Piper Div., Pettibone Mulliken Corp., Chicago was the speaker. Shown at the head table are: Chapter Treasurer T. Niven, Canadian Steel Foundries (1956) Ltd.; Chapter Vice-Chairman Max Reading, Foundry Services (Canada) Ltd.; Al Durrell, Dominion Engineering Works, Ltd.; speaker Madacey; Chapter Chairman Paul Von Colditz, Canadian Steel Foundries (1956) Ltd.; C. V. Nass, Beardsley Piper Div., Pettibone Mulliken Corp., Chicago; Chapter Director W. Tibbits, Canadian Steel Foundries (1956) Ltd.; and Chapter Secretary Leo Myrand, Montreal Foundry Ltd.—*F. Machin*

Cincinnati Chapter

Conduct F.E.F. Night

■ January's meeting was devoted to an explanation of Foundry Educational Foundation activities. Students holding F.E.F. scholarships and staff from universities in the area attended as guests. The students were given junior AFS memberships by the chapter.

Speakers for the evening were Anthony Haswell, Dayton Malleable Iron Co., Dayton, Ohio, and E. J. Walsh, executive-director, Foundry Educational Foundation, Cleveland.

Guests were:

University of Kentucky—Students, Donald O. Barnett, Leslie B. Claxton, Donald L. Daugherty, Gerald E. Otis, Patrick L. Murphy, David B. Routledge, Gerald Scott. Staff, Dean R. E. Shaver, Prof. Robert C. Duncan, Prof. Roy E. Swift.

University of Cincinnati — Students Terry Hollinger, J. P. Johannigman. Staff, Dean Howard K. Justice, Prof. Joseph W. Bunting, Prof. William Licht, Prof. Roy O. Duffie, Prof. Fred E. Westerman.

University of Dayton — Staff, R. B. Puckett.—*James D. Claffey*

British Columbia

Cover Non-Ferrous Operations in Meeting Held at Vancouver

■ The importance of melting, molding, and mechanization in non-ferrous operations was covered at the January meeting by William M. Ball, Jr., R. Lavin & Sons, Inc., Chicago.

Mr. Ball cited examples of good and bad foundry practice witnessed in his forty years' experience with the casting industry.—*J. T. Hornby*

Canton Chapter Gets Early Start on 1958-59 Program

■ Preliminary work has been started by the Canton Chapter on preparation of the 1958-59 program. A list of 16 subjects has been circulated to chapter members who are requested to list their 10 choices in order of preference. In addition to technical talks, the list includes a panel discussion, plant visitation, and Ladies' Night.

Metropolitan Chapter members held their annual Christmas party at the Essex House, Newark, N.J. The activities included a two-hour entertainment program. Robert Hunter, Archer-Daniels-Midland Co., served as chairman of the Christmas party committee.—*John R. Bing*

Saginaw Valley

Casting Trends in Autos

■ Pressures exerted upon the automobile manufacturers by the American public for new styling and innovations has resulted in new requirements for foundries, Saginaw Valley members heard at the January meeting.

Harry Gravlin, Chrysler Corp., Detroit, pointed out many of the new challenges facing foundries today such as new design, improved quality, and automation. Recent and future features such as turbine engines, air suspension, power steering, and decreased weight all pose special problems to the casting industry.—*R. J. Gleffe*

Participating in the January meeting were, left to right, Chapter Chairman Vern Sadler, speaker Gravlin, and Technical Chairman George Frye.

Timberline Chapter

Laws Affecting Foundries

■ Recent noise and air pollution legislation affecting foundries was explained at the January meeting by H. J. Weber, AFS Director of Safety, Hygiene, and Air Pollution Control. Denver currently is studying an air pollution abatement program. Weber outlined action various foundry groups have taken to participate in control programs.

The chapter's first Christmas party consisted of a dinner, dancing, and entertainment. Music was provided by musicians from Denver University and the Central City Opera. Ladies were provided with corsages and prizes.—*D. C. Card*

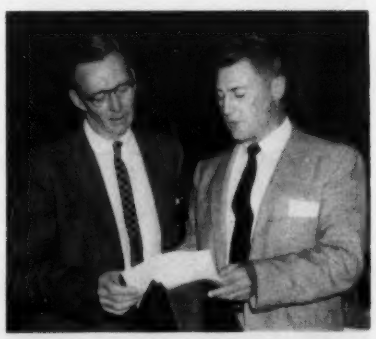
Quad City Chapter

Foundries and Customers

■ Lower production costs and maintenance of quality will broaden the casting market, Thomas Logan, Caterpillar Tractor Co., Peoria, Ill., told the January meeting. A closer liaison with customers to understand their problems will pay big dividends, he stated. Among the tools foundrymen have to meet competitive methods are shell molding, ductile iron, pearlitic malleable, and improved green sand molding techniques. Figures were cited on how customers saved money by converting from weldments, stampings and forgings to castings.—*William Ellison*

Foundrymen and their wives from the **Central Michigan Chapter** area had a near-capacity crowd at the annual Christmas party. The party was held at the Hart Hotel in Battle Creek, Mich.—*Richard F. Ell*

Casting defects caused by sand were covered at a meeting of the **Philadelphia Chapter** by George F. Watson, American Brake Shoe Co., center. Others are Chapter Chairman H. C. Winte, left, and Technical Chairman Daniel Jones.—*E. C. Klank*



Visiting Vice-President of **Northwestern Pennsylvania Chapter**, W. S. Hodge, compares notes with I. W. Sharp, right, **Pittsburgh's** Vice-President, during meeting at Pittsburgh. —*Walter Napp*

Ten past presidents of the **Chicago Chapter** were guests of honor at the January meeting which featured a discussion of "Problems and Prospects in Executive Development" by Robert L. Reid, University of Chicago. Left to right are: Jim Thomson, retired; Harold Johnson, Wells Mfg. Co.; L. H. Rudesill, Griffin Wheel Co.; W. D. McMillan, International Harvester Co.; C. V. Nass, Beardsley & Piper Div., Pettibone Mulliken Corp.; John Owen, Harbison Walker Refractories Co.; John Rassenfoss, American Steel Foundries; Robert Doelman, Miller & Co.; J. T. Moore, Wells Mfg. Co.; and Robert Schauss, Werner G. Smith, Inc.

Wisconsin Chapter

Sand Reclamation Panel

■ Sand reclamation systems were discussed at the January meeting by a three-man panel with P. C. Fuerst, Falk Corp., Milwaukee, acting as moderator. Three systems were discussed; wet, thermal, and pneumatic.

Panelists were: R. K. Strong, Hydro Blast Div., Guardite Co., Wheeling, Ill.; R. L. McIlvaine, National Engineering Co., Chicago; and W. R. Ellenberger, New York.

AFS President H. W. Dietert attended the chapter's Board of Directors meeting and also the technical session. He outlined the purposes and activities of the Society.—*Erich M. Sobota*

January's panel discussion was composed of R. K. Strong, panel moderator; P. C. Fuerst; R. L. McIlvaine; and W. R. Ellenberger.—*Bob DeBroux*

David C. Zuege, Sivyer Steel Casting Co., Milwaukee, and Everett Carpenter, Carpenter Bros., Inc., Milwaukee, assist Miss Patty Beach entertain the **Wisconsin Chapter** foundrymen at the annual Christmas party.—*Bob De Broux*

Chicago Chapter

Developing Executives

■ Many foundries are lagging badly in developing executives for administration duties in the future, Robert L. Reid, University of Chicago, warned foundrymen at the January meeting.

"Unless the general manager can honestly say that he has done a good job of developing a man to take his job should he become unavailable tomorrow, he has neglected his most important duty," said Reid. He pointed out that there is little use in sending executives or junior executives through expensive training programs unless management is willing to think progressively about the suggestions of the trainees when they return.—*I. H. Dennen*

R. L. Reid addressing Chicago Chapter

Birmingham Chapter

Hard Selling Needed

■ Aggressive selling combined with good management will lead to an increased market for the casting industry, Lester B. Knight, Lester B. Knight & Associates, Chicago, told members at the January meeting. Claude S. Lawson, U. S. Pipe & Foundry Co., Birmingham, Ala., outlined the history and progress of his company prior to the technical meeting.—*Dwight E. McGill.*

New Company Members

■ *An increasing number of foundries are securing company memberships in AFS. This entitles the company to a full membership service for an officially designated company representative. In addition it allows company employees within a chapter area to become personal members at the reduced price of $10. Following are those holding new company memberships and their chapter area.*

A & M Castings Co., South Gate, Calif., (Southern California)
Ajax Engineering Corp., Trenton, N.J. (Philadelphia)
Alloy Metal Abrasive Co., Ann Arbor, Mich. (Detroit)
American Refractory & Crucible Corp., New Haven, Conn. (Connecticut)
Arlington Texas Industries, Inc., Arlington, Texas. (Texas)
Baird Atomic Inc., Cambridge, Mass. (New England)
Blastcrete Service Co., Los Angeles, (Southern California)
British Industries Corp., Port Washinton, N. Y. (Metropolitan)
Cocker Machine & Foundry Co., Gastonia, N. C. (Piedmont)
Davis Fire Brick Co., Oak Hill, Ohio. (Central Ohio)
Ephrata Mfg. Co., Ephrata, Pa. (Philadelphia)
Eutectic Welding Alloys Corp., Flushing, N. Y. (Metropolitan)
Fremont Flask Co., Fremont, Ohio. (Toledo)
General Casting Co., Delaware, Ohio. (Central Ohio)
Great Lakes Foundry Sand Co., Detroit. (Detroit)
Hartley Controls Corp., Neenah, Wis. (Wisconsin)
Houghton Laboratories, Inc., Olean, N. J. (Northeastern Ohio)
King Tester Corp., Philadelphia. (Philadelphia)
Lowery Bros., Inc., Chicago. (Chicago)
Luria Bros. & Co., Los Angeles. (Southern California)
Mackintosh-Hemphill Co., Pittsburgh, Pa. (Pittsburgh)
Magnaflux Corp., Chicago. (Chicago)
National Crucible Co., Philadelphia. (Philadelphia)
Ohio Crankshaft Co., Cleveland. (Northeastern Ohio)
Rotor Tool Co., Cleveland. (Northeastern Ohio)
Scientific Cast Products Corp., Cleveland. (Northeastern Ohio)
A. O. Smith Corp., Milwaukee. (Wisconsin)
G. H. Tennant Co., Minneapolis. (Twin City)
U. S. Electrical Tool Co., Cincinnati. (Cincinnati.)

afs chapter meetings

MARCH

Birmingham District . . March 14 . . Thomas Jefferson Hotel, Birmingham, Ala. . . J. F. Orloff, Central Foundry Div., Saginaw Malleable Iron Plant, GMC, *"Gating to Control Pouring & Its Effect on the Casting."*

British Columbia . . March 21 . . Pacific Athletic Club, Vancouver . . O. J. Myers, Reichhold Chemicals, Inc., *"Recent Developments in the Field of Coremaking."*

Canton District . . March 6 . . Mergus Restaurant, Canton, Ohio . . J. A. Babcock, Pickands Mather & Co., *Film on Mining & Smelting of Taconite Ore.*

Central Illinois . . March 3 . . American Legion Hall, Peoria, Ill. . . O. J. Myers, Reichhold Chemicals, Inc., *"Sand."*

Central Indiana . . March 3 . . Athenaeum Turners, Indianapolis . . H. H. Kessler, Sorbo-Mat Process Engineers, *"Gating & Risering."*

Central Michigan . . March 19 . . Hart Hotel, Battle Creek, Mich. . . O. H. Kastens, Newago Engineering Co., *"Mechanization in the Small Foundry."*

Central New York . . March 14 . . LeMoyne Manor, Syracuse, N. Y. . . Fr. McKean, LeMoyne College, *"Industrial Relations."*

Central Ohio . . March 10 . . Seneca Hotel, Columbus, Ohio . . H. J. Weber, AFS, *"Legislation Affecting Foundries."*

Chesapeake . . March 28 . . Engineers' Club, Baltimore, Md. . . H. F. Bishop, Exomet, Inc., *"Gating & Risering."*

Chicago . . March 3 . . Chicago Bar Association, Chicago . . E. C. Zirzow, Werner G. Smith, Inc., *"Why Four Methods of Coremaking?"*

Cincinnati District . . March 10 . . Suttmiller's Restaurant, Dayton, Ohio . . H. Brown, Metallurgical Associates, Inc., *"Techniques of Selling Castings—Profitably."*

Connecticut . . March 25 . . Waverly Inn, Cheshire, Conn. . . *"New Developments in the Foundry."*

Corn Belt . . March 14 . . Fireside Restaurant, Omaha, Neb. . . W. M. Ball, R. Lavin & Sons, Inc., *"Non-Ferrous Melting Practice."*

NATIONAL OFFICERS AND DIRECTORS

PRESIDENT
Harry W. Dietert

VICE-PRESIDENT
L. H. Durdin

REGIONAL VICE-PRESIDENTS

Region 1	East	O. J. Myers
Region 2	Central	C. W. Gilchrist
Region 3	Midwest	A. V. Martens
Region 4	South Southwest	R. W. Trimble
Region 5	Pacific Coast	J. R. Russo

Terms expire 1960

W. D. Dunn	A. A. Hochrein
K. L. Landgrebe, Jr.	F. J. Pfarr
J. R. Russo	A. M. Slichter
H. G. Stenberg	

Terms expire 1959

C. E. Drury	R. W. Griswold
H. Heaton	A. V. Martens
G. P. Phillips	A. W. Pirrie
G. R. Rusk	

Terms expire 1958

C. C. Drake	H. C. Erskine
C. W. Gilchrist	C. E. Nelson
O. J. Myers	F. W. Shipley
R. A. Oster	R. W. Trimble

Detroit . . March 20 . . Prince Edward Hotel, Windsor, Ont. . . W. L. Cisler, Detroit Edison Co., *"Effect of Atomic Power Development in This Area."*

Eastern Canada . . March 21 . . Sheraton-Mt. Royal, Montreal, Que. . . G. L. Barrett, Dominion Engineering Works, Ltd., R. Woods, Montreal Bronze, Ltd., and A. Bain, Canadian Iron Foundries, Ltd., *"Cleaning Shop Practices."*

Eastern New York . . March 18 . . Panetta's Restaurant, Menands, N. Y.

Metropolitan . . March 3 . . Essex House, Newark, N. J. . . O. H. Kastens, Newaygo Engineering Co., *"Small Foundry Mechanization." Film and Discussion Period.*

Mexico . . *No Information Available.*

Michiana . . March 10 . . Club Normandy, Mishawaka, Ind. . . C. A. Sanders, American Colloid Co., *"It's Not All Sand."*

Mid-South . . March 14 . . Hotel Claridge, Memphis, Tenn. . . Z. Madacey, Beardsley & Piper Div., Pettibone Mulliken Corp., *"Coremaking."*

Mo-Kan . . March 7 . . Fairfax Airport, Kansas City, Kans. . . C. E. Wenninger, Beardsley & Piper Div., Pettibone Mulliken Corp., and R. W. Trimble, Bethlehem Supply Co., *"Digging Into Sand Fundamentals."*

New England . . March 12 . . University Club, Boston . . L. W. Greenslade, Brown & Sharpe Mfg. Co., *"Problems of Gating & Risering."*

Northeastern Ohio . . March 13 . . Tudor Arms Hotel, Cleveland . . W. E. Sicha, Aluminum Co. of America, *"Production of Sound Castings."*

Northern California . . March 17 . . Spenger's Cafe, Berkeley, Calif. . . O. J. Myers, Reichhold Chemicals, Inc., *"Sand & Core Binders."*

Northern Illinois & Southern Wisconsin . . March 11 . . Country Club, Beloit, Wis. . . *Apprentice Night and Panel Discussion. Moderator:* R. M. Lightcap, Rupp Pattern Co.

Northwestern Pennsylvania . . March 24 . . Amity Inn, Erie, Pa. . . M. H. Horton, Deere & Co., *"Water-Cooled Cupola-Construction, Economics, Operations & Problems."*

Ontario . . March 28 . . Royal York Hotel, Toronto, Ont. . . H. H. Kessler, Sorbo-Mat Process Engineers, *"Melting & Molding."*

Oregon . . March 19 . . Heathman Hotel, Portland, Ore. . . O. J. Myers, Reichhold Chemicals, Inc., *"Recent Developments in Coremaking."*

Philadelphia . . March 14 . . Engineers' Club, Philadelphia . . R. R. Wily, Bethlehem Steel Co., *"Safety for Foundrymen."*

Piedmont . . March 7 . . Hotel Goldsboro, Goldsboro, N. C. . . R. A. Clark, Electro Metallurgical Co., Div. Union Carbide Corp., *"Gray Iron Foundry Practice."*

Pittsburgh . . March 17 . . Hotel Webster Hall, Pittsburgh, Pa. . . D. C. Ekey, Georgia Institute of Technology, *"Recent Developments in Molding in the Foundry."*

Quad City . . March 17 . . Hotel Ft. Armstrong, Rock Island, Ill. . . T. A. Boyd, General Motors Research Consultant. *Management Night.*

Rochester . . March 4 . . Hotel Seneca, Rochester, N. Y. . . G. L. Moore, Aluminum Co. of America, *"Designing Aluminum Castings for Production & Serviceability."*

St. Louis . . March 13 . . Edmond's Restaurant, St. Louis . . A. F. Pfeiffer, Allis-Chalmers Mfg. Co., *"Coordinative Function of Pattern Equipment & Castings."*

Saginaw Valley . . March 6 . . Fischer's Hotel, Frankenmuth, Mich. *Student Night.*

Southern California . . March 14 . . Rodger Young Auditorium, Los Angeles . . O. J. Myers, Reichhold Chemicals, Inc., *"Recent Developments in Coremaking."*

Tennessee . . March 28 . . Patten Hotel, Chattanooga, Tenn. . . M. J. Kellner, Westinghouse Electric Corp., *"An Approach to a Profitable Foundry."*

Texas . . March 21 . . Western Hills Hotel, Ft. Worth, Texas . . *Panel Discussion by Casting Users.*

Texas, East Texas Section . . March 21 . . *Joint meeting with Texas Chapter.*

Texas, San Antonio Section . . March 24 . . Alamo Iron Works, San Antonio, Texas.

Timberline . . March 10 . . Oxford Hotel, Denver, Colo. . . W. M. Ball, R. Lavin & Sons, Inc., *"Non-Ferrous Melting Practice."*

Toledo . . March 5 . . Heather Downs Country Club, Toledo, Ohio . . B. H. Taylor, The B. F. Goodrich Co., *"Today's Challenge in Human Relations."*

Tri-State . . March 14 . . Western Village Motel, Tulsa, Okla. . . H. J. Weber, AFS, *"Legislation Affecting Foundries."*

Twin City . . March 11 . . Jax Restaurant, Minneapolis . . M. K. Young, U.S. Gypsum Co., *"Models & Molds for Plastics."*

Utah . . March 24 . . Park's Cafe, Orem, Utah . . O. J. Myers, Reichhold Chemicals, Inc., *"Recent Developments in Coremaking."*

Washington . . March 20 . . Engineers' Club, Seattle . . O. J. Myers, Reichhold Chemicals, Inc., *"Recent Developments in Coremaking."*

Western Michigan . . March 3.

Western New York . . March 7 . . Sheraton Hotel, Buffalo, N.Y. . . S. C. Massari, AFS, *"Horizontal Gating Systems."*

Wisconsin . . March 14 . . Schroeder Hotel, Milwaukee . . *Sectional Meeting.*

APRIL

Birmingham District . . April 11 . . Anniston, Ala. . . H. H. Wilder, Vanadium Corp. of America, *"Cupola Operations."*

British Columbia . . April 18 . . Pacific Athletic Club, Vancouver, B. C. . . J. E. Wilson, Climax Molybdenum Co., *"Factors Affecting the Behavior of Steel Castings."*

Canton District . . April 3 . . Elks Club, Alliance, Ohio . . H. A. Stuhldreher, U. S. Steel Corp., *National Officers' Night.*

Central Illinois . . April 7 . . American Legion Hall, Peoria, Ill.

Central Indiana . . April 7 . . Athenaeum, Indianapolis . . R. C. Frank, Superior Steel & Malleable Castings Co., *"The Big Difference."*

Central New York . . April 11 . . Statler Inn, Ithaca, N. Y. . . C. A. Sanders, American Colloid Co., *"Ithaca Sand."*

Central Ohio . . April 14 . . Seneca Hotel, Columbus, Ohio . . *Apprentice and Education Night.*

Chesapeake . . April 25 . . Engineers' Club, Baltimore, Md. . . *"Castings Clinic."*

Chicago . . April 7 . . Chicago Bar Association, Chicago . . *Gray Iron & Malleable Group*: W. D. McMillan, International Harvester Co., *"Water Cooled Cupola Operation"*; *Steel Group*: R. Ames, U. S. Steel Corp. South Works, *"Refractories & Ladle Practice"*; *Maintenance Group*: E. W. Greenlees, Kensington Steel Co., *"Aches & Pains of Foundry Maintenance"*; *Non-ferrous & Pattern Group*: M. Glassenberg, Armour Research Foundation, *"Eliminating Leakage in Navy 'G' Pressure Castings."*

Cincinnati District . . April 14 . . Alm's Hotel, Cincinnati . . M. K. Young, U. S. Gypsum Co., *"Epoxy Resin Patterns for the Foundry Industry."*

Eastern Canada . . April 11 . . Sheraton-Mt. Royal Hotel, Montreal, Que. . . H. A. Burton, Canadian Steel Foundries, Ltd., *"Review of Use of Reinforced Resins."*

Metropolitan . . April 7 . . Essex House, Newark, N. J. . . O. J. Myers, Reichhold Chemicals, Inc., *"Sand Processes."*

Michiana . . April 14 . . Club Normandy, Mishawaka, Ind. . . C. A. Koerner, Central Foundry Div., GMC, *"New Foundry Testing Methods."*

Mid-South . . April 11 . . Hotel Claridge, Memphis, Tenn. . . *Casting Clinic.*

Mo-Kan . . April 4 . . Fairfax Airport, Kansas City, Kans. . . R. Cochran, R. Lavin & Sons, Inc., *"Pouring Good Brass Castings."*

New England . . April 9 . . Massachusetts Institute of Technology, Cambridge, Mass., *Tech Night.*

Northeastern Ohio . . April 10 . . Tudor Arms Hotel, Cleveland . . E. A. Walcher, Jr., American Steel Foundries, *"Building a Modern Foundry Organization."*

Northern California . . April 14 . . Spenger's, Berkeley, Calif. . . A. Castignola, G. Wetstein, and M. Thomas, *"Plastic, Plaster Cast & Shell Patterns."*

Ontario . . April 25 . . Seaway Hotel, Toronto, Ont. . . *Annual Ladies' Night.*

Philadelphia . . April 11 . . Engineers' Club, Philadelphia . . *Round Table; Nonferrous*: J. D. Allen, Jr., Federated Metals Div., American Smelting & Refining Co.; *Cast Iron*: J. S. Vanick, International Nickel Co.; *Steel*: J. Juppenlatz, Quaker Alloy Casting Co., *"New Developments in Cast Metals."*

Piedmont . . *No Meeting.*

Pittsburgh . . April 21 . . Hotel Webster Hall, Pittsburgh, Pa. . . T. W. Curry, Lynchburg Foundry Co., *"Ductile Iron."*

Quad City . . April 21 . . Hotel Ft. Armstrong, Rock Island, Ill. . . R. Andrews, Demmler Mfg. Co., *"Blown Shell Molding—Evaluation & Exploitation."*

Rochester . . April 1 . . Hotel Seneca, Rochester, N. Y. . . L. G. Burwinkel, Jr., Pennsylvania Glass Sand Corp., *"Occurrence, Production & Uses of Quality Silica."*

Sagniaw Valley . . April 3 . . Fischer's Hotel, Frankenmuth, Mich. . . H. A. Wichert, Personnel & Business Consultant, *"Humanics."*

St. Louis . . April 10 . . Edmond's Restaurant, St. Louis . . L. D. Pridmore, International Molding Machine Co., *"Core and Mold Blowing."*

Tennessee . . April 25 . . Patten Hotel, Chattanooga, Tenn. . . C. C. Sigerfoos, Michigan State University, *"Opportunities in the Foundry Industry."*

Texas . . April 18 . . Angelina Hotel, Lufkin, Texas.

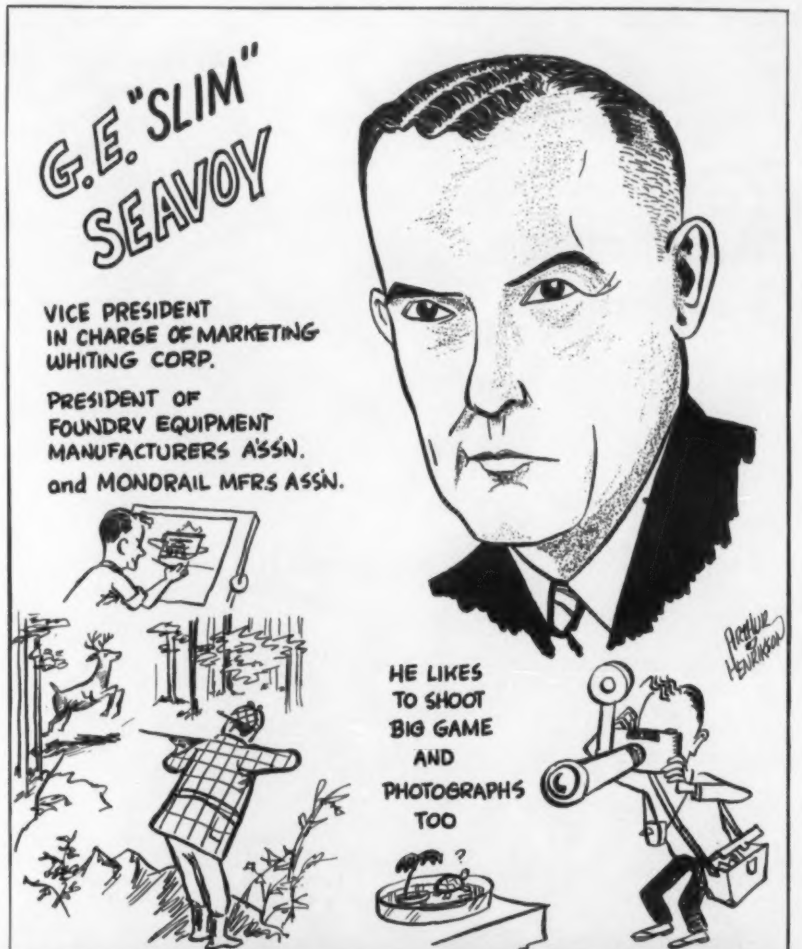
Toledo . . April 2 . . Heather Downs Country Club, Toledo, Ohio . . W. G. Ferrell, Auto Specialties Mfg. Co., *"How Health & Hygiene Affect Foundry Cost."*

Tri-State . . April 18 . . Western Village Motel, Tulsa, Okla. . . *Round Table Discussion.*

Twin City . . April 8 . . Jax Restaurant, Minneapolis . . V. M. Rowell, Harry W. Dietert Co., *"Synthetic Sand Practice."*

Utah . . *No Meeting.*

Wisconsin . . April 11 . . Schroeder Hotel, Milwaukee . . *Management Night.*



Personalities

obituaries

Henry J. Jameson, 70, retired vice-president and director, Detroit Testing Laboratory Inc., died Jan. 18. He was a member of the AFS Detroit Chapter for many years, and served on several AFS technical committees. Last summer, he donated his services to teach one of the sand courses conducted by the AFS Training & Research Institute.

Born in Istanbul, Turkey, Jameson was with Detroit Testing Laboratory Inc. from 1911 until his retirement in 1954; since then, he was affiliated with the Harry W. Dietert Co., Detroit.

Dr. W. R. Whitney, 89, founder of the General Electric Research Laboratory, and honorary vice-president of the General Electric Co., Schenectady, N. Y., died Jan. 9.

Born in Jamestown, N. Y., Dr. Whitney graduated from Massachusetts Institute of Technology in 1890, and received his Ph.D. in chemistry from the University of Leipzig, Germany, in 1896.

He held several positions at M.I.T., and did research in electrochemistry until joining General Electric in 1900; he was director of the company's research laboratory until 1932. He then held the position of vice-president in charge of research until his retirement in 1941. Dr. Whitney continued research in the capacity of honorary vice-president and consultant to the laboratory.

Harlow Adams, 62, president of the Adams Co., Dubuque, Iowa, died Jan. 29. He was born in Hinsdale, Ill. and graduated from Northwestern University, Evanston, Ill., in 1919. He had been associated with the Adams Co., manufacturer of machine tools and foundry equipment, since his graduation from the university.

John H. Merrell, honorary director, Raybestos-Manhattan, Inc., Passaic, N. J., died Jan. 4. He had been with the company for 54 years.

George M. Parker, foreman, Florence Pipe Foundry & Machine Co., Florence, N. J., died recently. He was a member of AFS, the Philadelphia Chapter.

Manual of Safety in Welding, Cutting, and Related Operations Now Available

■ SAFE PRACTICES MANUAL FOR WELDING, CUTTING, BRAZING, SOLDERING, AND SIMILAR OPERATIONS, a new AFS publication, is a product of the Welding Committee (Safety), formed for developing recommended practices relating to the health and safety of workers engaged in gas and electric cutting, welding, brazing, soldering, and similar operations.

One chapter, Fuel Gas and Oxygen Service Piping Systems, describes precautions and safe procedures for the following:

- Acetylene gas and oxygen gas piping
- Inspection and cleaning of pipe fittings
- Types of permissible pipe joints and make-up of threads
- Piping installation
- Pipe lines installed in tunnels, trenches, and basements
- Drip pots for low points on piping systems
- Testing of fuel gas and oxygen gas lines
- Hydraulic back-pressure valves and portable headers

Storage, maintenance, transportation, use of gas cylinders are treated in detail; and common causes of damage to those lines are listed.

Arc cutting and welding, and resistance welding precautions are described in the manual. Prevention of electrical shock by proper grounding, electrical disconnect switches, lock outs, safe use of the electrode holder, and correct cable splices are stressed.

Fires often result from careless welding and cutting practices. For this reason, fire and explosion hazards and the proper preventive measures are reviewed.

The manual emphasizes ventilation of various fume sources. General and local ventilations are treated in detail with rules established concerning use of booths, hoods, general or natural ventilation.

Emphasis is placed on precautions to be followed when working on toxic materials or materials having toxic coatings such as lead, cadmium, etc.

Air velocity and volumes are given for exhaust systems. Air velocity at the *point of generation* of gases, dusts, smoke, and fumes are used as the basis for determining hood and booth designs.

The chapter on personal protection prescribes equipment for protection against radiation, heat, and sparks. Lens density and absorption are determined by the type of work, and in the case of arc welding, by the amount of current (amperage) needed for operation.

Ten recommendations are listed for protective clothing in order to prevent injury to the welder from burns commonly suffered when no protection is provided.

Because of the many hazards involved in generator houses and calcium carbide storage rooms, the manual covers detailed construction and operating precautions for these areas.

The safe practices prescribed throughout the manual, if adopted, will eliminate injuries and fires resulting from such operations; and should tend to bring about uniform procedures in the foundry industry.

AFS members may purchase the book for $3.00; the non-member price is $4.50. Write to: Book Department, American Foundrymen's Society, Golf and Wolf Roads, Des Plaines, Ill.

Resolution urging passage of the Sadlak-Herlong bill for personal and corporate income tax reduction was among actions taken by the Board of the **Non-Ferrous Founders' Society** during a fall meeting held in St. Louis. The resolution was transmitted to the House Ways & Means Committee. Seated, left to right are: Elmer G. Brumund, Jr., Wm. L. Leopold, S. Oscar Swangren, Harvey D. Fishel, William Grimm, Robert Langsenkamp, Phillip E. Lankford, Charles J. Egetter, Herbert F. Scobie. Standing, left to right: Albert J. Messmer, Edw. J. Metzger, Wm. A. Gluntz, H. A. White, L. J. Andres, Robert E. Dickison, James H. Brennan, M. E. Nevins, George T. Fischer, Gunnard A. Eliason.

Chemical Treating of Metal Calls for Detailed Study

by R. W. RUDDLE / *Technical Manager Foundry Services, Inc. Columbus, Ohio*

■ Of the several standard chemical methods of treating molten non-ferrous alloys, I should like to emphasize that the precise treatment to be employed in any given case depends upon several factors: type of melting unit and fuel, the alloy being treated, form of charge, type of casting, and others. Expert advice should generally be sought before a new type of treatment is adopted.

Main purposes of chemical treatment are: reduction in melting losses, prevention of dross formation, removal of gases, and production of correct grain structure in the casting.

Melting Losses

The extent to which metal is lost during melting as a result of oxidation varies considerably with the type of furnace used; reverberatory type furnaces exposing a large surface showing the biggest loss, electric furnaces the smallest.

A commonly used cover to reduce metal loss is a layer of charcoal on the surface of the melt. Charcoal covers are much less effective on alloys where certain elements, such as zinc, are lost by volatilization. In such cases a fluid flux cover is more effective.

Three classes of fluxes are used with aluminum alloys: fluid covers which minimize oxidation losses and dissolve oxide particles in the melt; drossing off fluxes to insure that skimmings contain minimum amounts of aluminum; and modifying fluxes to modify aluminum/silicon alloys.

Gas Removal

The principal gases found in metals which cause trouble during solidification are hydrogen and its compounds – steam, carbon monoxide, sulfur dioxide, etc. Hydrogen removal can be accelerated by stirring the metal under a flux cover which absorbs the oxide on the surface, removing one of the barriers to outward diffusion. More rapid removal can be achieved by purging the melt with an inert gas, insoluble in the metal.

Steam is formed in the melt as oxygen combines with hydrogen. One method of insuring that oxygen and hydrogen contents shall both be low is to melt under a reducing flux or charcoal, preventing oxygen pick-up and at the same time permitting hydrogen into the melt. The hydrogen must be removed later by nitrogen degassing or other means.

■ Condensed from a talk presented at the New England Foundry Conference, held at Massachusetts Institute of Technology Oct. 18, 1957.

let's get personal

General Grinding Wheel Corp., Philadelphia, has announced the election of **Clarence Tolan, Jr.** as chairman of the board of directors and **Jacob S. Disston, Jr.** as vice-chairman.

Paul R. Gouwens . . has joined the metals research staff of Armour Research Foundation, Illinois Institute of Technology, Chicago, as supervisor of the foundry and steelmaking section of the department. He recently has been appointed vice-chairman of the Electric Furnace Steel Conference of the American Institute of Mining, Metallurgical, and Petroleum Engineers for 1958.

T. H. Booth . . has been elected president of Frontier Bronze Corp., Niagara Falls, N. Y. He succeeds **E. H. Holzworth,** who has retired after serving as the firm's president for 31 years.

S. C. Northington . . is the new superintendent of foundries for Combustion Engineering, Inc., Chattanooga, Tenn. He was formerly foundry consultant for the firm.

James L. Jackson . . has been appointed sales manager for Burnside Steel Foundry Co., Chicago.

H. H. Bertrand . . has been named vice-president—plant engineering, Chicago; and **J. M. Planten,** vice-president—plant engineering, New York; by Lester B. Knight & Associates, Inc., Chicago.

B. M. Johnson . . vice-president, Carborundum Co., Niagara Falls, N. Y., has been named general manager of the company's new Refractories Div. Other appointments were: **Robert A. Barr** to assistant general manager in charge of sales, and **A. L. Leo-Wolf** to assistant general manager in charge of operations. Johnson, Barr, and Leo-Wolf were formerly general managers of the Refractories, Stupakoff, and Globar Div. respectively, now merged into the new Refractories Div.

George Anders . . formerly foundry foreman for P.M.S. Co., Cleveland, has been named foundry consultant for Cleveland Electro Metals Co.

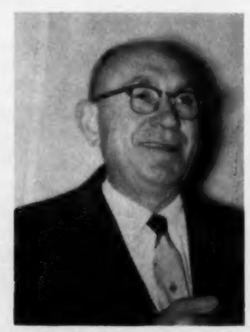
Stanley Hoot . . Carson, Marshall & Co. Inc., Philadelphia, has been promoted from vice-president to president of the organization. **J. P. Hoot** formerly secretary, is the new vice-president.

C. H. Cline . . is the new general superintendent, H. G. Enderlein Co., Philadelphia. He was formerly the assistant general manager, Palmyra Foundry, Palmyra, N. J.

E. E. Mueller . . Whirl-Air-Flow Corp., is the new president of the firm. Other promotions include: **R. G.**

T. H. Booth

J. M. Planten



C. H. Cline

Pence, G. W. Anselman, and G. L. Babcock to the position of vice-president. Mueller was president of the Foundry Supply Co., Minneapolis, before joining Whirl-Air-Flow last September. The three vice-presidents have been with the firm since 1953. The corporation's new address is 650 Twenty-fifth Ave., S.E., Minneapolis 14, Minn.

John W. Phillippe . . has been named Michigan district manager for Acme Resin Corp. He was formerly em-

J. W. Phillippe

ployed as supervisor of the shell molding department for International Harvester Co., Indianapolis, Ind.

Michael A. Horlak . . has been named new product research and development engineer for Rotor Tool Co., Cleveland. He is a former chairman of the education committee, Northeastern Ohio AFS Chapter.

G. P. Krumlauf . . has been named assistant to the manager of sales, Pig Iron and Coal Chemicals Div., Re-

G. P. Krumlauf

public Steel Corp., Cleveland. He was formerly associated with the Hamilton Foundry and Machine Co., Hamilton, Ohio.

Continued on page 135

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Best Ladle Lining

continued from page 38

If a form is used when ramming the bottom and sidewalls, the sidewalls should be rammed again after form is removed. This time with the hammer in a horizontal position. A surprising number of soft spots will be found, usually at the parting lines of the different layers of the mix, even though a good job of scratching the surface between layers had been done.

Linings may be air dried over night, if time permits, or heated to about 400 F in 8 to 10 hours. Ladle lining may be dried with a gas burner flame applied to the inside of the ladle, or by placing in a core oven. After this drying period, a torch should be used to bring the lining up to a cherry red heat. The time required for this preheating may vary from an hour up to 10 or 12 hours depending upon the size of ladle involved and the type refractory used.

Each foundryman must determine the most efficient and satisfactory drying cycle to give the longest refractory life. Labor costs can be reduced substantially by reducing ladle repairs and increasing refractory service.

New Materials

There are on the market today, a number of new refractory products for use in ladle linings. Most of these are plastic refractories that have been available and in use for many years. Some of these are in the super duty class, with higher fusion points, less shrinkage, and greater spalling resistance. Graphite bearing plastics are claimed to have greater workability.

Refractory castables are receiving more attention, particularly for ladle covers. Fusion temperatures have been increased; and it is very simple to pour-up a new lid in a hurry. These castables reach maximum strength and are ready for service in 24 hours.

A further consideration when selecting the proper ladle refractory must be made between manufactured refractory products and special mixes prepared by the

foundryman himself. Many of these home-made blends do an excellent job, and prove more economical to use than any purchased product. It is not the question of quality, but the trouble and expense involved when the foundry operator does his own mixing and blending. To some, this may be no problem, but to others it can mean costly down time and high labor costs for refractory preparation.

Every foundryman is doing his best to *"make"* money and one of the sure ways of accomplishing this is to *"save"* money. Ladle refractories and their installation should not be overlooked when trying to find places where money can be saved. It may mean cheaper priced material. It may be a longer lasting product—although its initial price is higher. It may be a material more easily installed or one that will substantially reduce scrap castings. So, get the most out of your ladles, both in good castings, and lower costs.

■ To obtain single additional copies of this article, circle E, Reader Service Card, page 7-8.

Business Failure Survey Reveals Traps to Avoid

■ Results of a recent survey directed by A. M. Woodruff, University of Pittsburgh, Pittsburgh, Pa., of ten small business concerns which had failed have brought to light several traps to avoid in small business management.

Inadequate records often cause waste and a lack of sound basis for estimating the worth of the concern. In several cases, serious losses were traced to a series of seemingly insignificant small leaks of which management was unaware.

In most of the cases studied, trouble resulted from the growth of the business beyond the scope of a bookkeeping system which had been used while the firm was small.

Two companies undertook substantial ventures without any marketing research. Contracting the entire plant output to a single buyer has resulted in real hazards.

Woodruff concludes that to stay competitive, managers must manage. This means planning, organizing, coordinating, and controlling—for the firm as a whole, not just for production or sales.

■ For a complete copy of this report, circle No. G pages 7-8.

here's how

■ Here's how **P & S Pattern Shop,** New York, fights the problem of limited floor space. Shop has been

equipped with power tools which use minimum floor space and which can be moved around the shop.

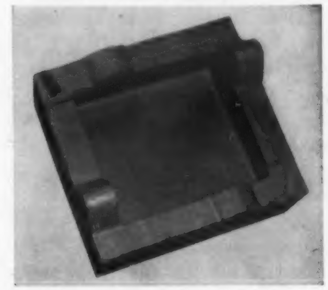
■ Here's how **Reliance Regulator Div., American Meter Co., Inc.,** tests ductile iron meter bodies. A 2400-lb drop ball was dropped 20 ft onto an assembled meter with only slight

deformation of the casting as a result. The Reliance plant at Alhambra, Calif., produces these meters for use in gas transmission service.

■ Here's how **Foundry and Mill Machinery Div., Blaw Knox Co.,** helps bridge builders. Blaw Knox Coraopolis Works cast two 26-ton steel cast-

ings that will become the foundation pedestals for Pittsburgh's new Fort Pitt bridge.

■ Here's how **Congress Die Casting Div., Tann Corp.,** Detroit, uses a cast-to-shape die retainer. The retainer was cast in steel by Forging and



Casting Div., Allegheny Ludlum Steel Corp., Pittsburgh. The 650 lb casting replaces a forged die block at a saving said to be over $1000. Cast-to-shape die retainers are recommended to replace forged die blocks for dies weighing over 400 lb. The

first photo shows the die retainer as delivered to the machine shop, and the second shows the completed retainer installed on the die casting machine.

■ Here's how giant castings produced by **Aluminum Co. of America** help aircraft builders. This 7500-lb casting is the largest of four castings which will be assembled into a wing fabri-

cating table. Weight and machinability were said to be reasons for building table from aluminum castings. Alcoa's Columbus, Ohio foundry cast the parts in sand molds. Alloy was 355-T7 E9.

foundry trade news

STEEL FOUNDERS' SOCIETY

■ Steel Founders' Society of America hosted 562 representatives of 123 foundries at the 12th Annual Technical & Operating Conference, held at the Carter Hotel, Cleveland, in November.

T. A. Cosh, British Steel Castings Research Association; and L. W. Sanders, Lake & Elliott, Ltd., Braintree, Essex, England, presented the first of a series of exchange lectures between the Steel Founders' Society and the British Association. The British representatives presented, jointly, *"The Carbon Rod Resistor Furnace and its Application to Steelmaking Practice,"* and *"The Use of the Dip Thermocouple Technique in British Foundry Practice."*

Thirty papers by 40 authors and co-authors, including C. E. Sims, Battelle Memorial Institute; P. J. Ahearn, of Watertown Arsenal, Watertown, Mass.; and G. R. Gorbell, Monsanto Chemical Co., St. Louis; were included in the program.

Organization and procedure of the conference was in charge of C. W. Briggs, S.F.S.A. Technical Research Director.

The Society will hold its 1958 Annual Meeting at the Drake Hotel, Chicago, March 17-18. Karl E. Mundt, Republican senator from South Dakota, will address members on *"What Lies Ahead in Labor Lgislation."*

Fred Smith, management consultant, Cincinnati, will talk on, *"How to Quarterback the Team."* J. B. Thomas, Texas Electric Service Co., Fort Worth, Texas, will discuss, *"Power Development."* Dr. W. H. Alexander, Oklahoma City, Okla., chaplain, Republican Party, 1952, is to be the luncheon speaker.

LEHIGH VALLEY FOUNDRYMEN ASSOC.

■ Members of the Lehigh Valley Foundrymen's Association, in the December meeting held at Lafayette College, Easton, Pa., learned of the latest developments in foundry practice as related by W. F. Straight, Bethlehem Steel Co., Quincy, Mass.

His talk entitled, *"Engineered Castings,"* illustrated with slides and sample castings, depicted means by which many castings may be cast to close tolerances, with machining costs reduced by as much as 50-75 per cent. The CO_2 core-hardening process, along with careful attention to good foundry practice, were mentioned as means of obtaining better castings and increased profits for the foundry industry.

Straight pointed out that on numerous castings machining has been entirely eliminated, including the production of elliptical holes now made by cores alone. Of particular interest were threaded fittings cast accurately to size by the CO_2 process. D. E. Best, Bethlehem Steel Co., acted as chairman for the technical meeting.

FOUNDRY EDUCATIONAL FOUNDATION

■ Trustees of the Foundry Educational Foundation, Cleveland, have approved establishment of an F.E.F. scholarship program at Virginia Polytechnic Institute, Blacksburg, Va. This is the seventeenth college to be included in the program.

Established in 1872, V.P.I. has grown to be one of the nation's leading technical educational institutions. Forty-four per cent of the engineers now employed by Virginia's leading foundries are graduates of the school.

A cooperative program in engineering and physics is offered at the Institute. Students are given an opportunity to gain practical industrial experience in their particular field of study. The co-op plan also provides opportunity for students to obtain funds for educational expenses.

The F.E.F. program will be under the direction of Dean J. W. Whittemore of the School of Engineering. Dr. J. F. Eckel, departmental head, metallurgical engineering, will act as F.E.F. key professor; and the foundry laboratory courses will be conducted by J. W. Strickler.

F.E.F. Trustee C. W. McLennan, Lynchburg Foundry Co., Lynchburg, Va., will represent the Foundation's board of trustees in working with faculty representatives on the new program.

DIE CASTING ENGINEERS

■ The Society of Die Casting Engineers, Inc., Detroit, has announced election of national officers for 1958. They are: Harry Cagin, Halex Die Casting Co., Cleveland, president; D. L. Rockwell, Clifford-Rockwell Co., Detroit, vice-president; M. R. Tenenbaum, Lester-Phoenix, Inc., Detroit, secretary-treasurer; W. Van Raaphorst, American Mold Engineering Co., Charlevoix, Mich., director; H. R. Shimel, Detroit, director; John Lapin, Saginaw Bay Industries, Inc., Bay City, Mich., director; and H. J. Windolph, Holland Die Casting, Inc., Holland, Mich., director.

MATERIAL HANDLING INSTITUTE

■ Material Handling Institute, Inc., Pittsburgh, Pa., elected R. L. Fairbank, Towmotor Corp., Cleveland, to president at the Institute's annual meeting held in New York during December.

Institute members also elected Eugene Caldwell, Baker-Raulang Co., Cleveland, to serve as first vice-president; and C. L. Fell, American Monorail Co., Cleveland, as second vice-president. The officers were elected for terms of one year.

AMERICAN DIE CASTING INSTITUTE

■ American Die Casting Institute, New York, has announced the availability of three series of die casting standards; engineering, metallurgical, and commercial, in a hard-covered ring binder.

Delta Oil Products Corp. . . is newly incorporated organization which will continue the business of Delta Oil Products Co., Milwaukee. W. T. Hansen is president of the new corporation, and J. A. Gitzen is chairman of the board. Gitzen was president and board chairman prior to the incorporation. Service and management policies of the firm are not affected by the changes.

Kolcast Industries, Inc. . . Minerva, Ohio, is installing what the company terms the world's largest induction furnace. Capacity of the furnace will be 350 lb. The new furnace will supply investment castings for jet en-

Golden Foundry Co. . . Columbus, Ind., was the scene of an open house in January sponsored by the American Air Filter Co., Louisville, Ky., to display a new cupola dust control system installed at the foundry. Approximately 60 mid-west foundrymen attended the open house; in addition to a complete explanation and tour of the dust control system, they received a short inspection trip through the foundry which casts gray iron automotive engine blocks.

A Golden Foundry official stated that the cupola dust control system was installed primarily to maintain good relations with residents who had moved into the foundry area. In addition, the dust control system eliminated paint damage to automobiles parked in the company parking lot; reduced roof cleaning maintenance; and controlled dust without excessive use of water, an important factor for the Golden Foundry.

gine, electronic, guided missile, atomic energy, and precision parts industries. Kolcast will use the furnace to manufacture castings in sizes up to 45 in.

National Cylinder Gas Co. . . Chicago, has established four new divisions and a foreign operation subsidiary. New divisions are: N. C. G. Div., and Chemical Products Div., both of Chicago; and Girdler Construction and Girdler Process Equipment divisions, both of Louisville, Ky. The new foreign subsidiary will operate the company's gas-producing business in Canada, Venezuela, Colombia, and other countries.

Casting Engineers Inc. . . Chicago, has stated through its president, V. S. Lazzara, that the investment casting industry can expect an unparalleled growth in the next five years, with sales for his company to non-defense industries expected to reach an all-time high of over 19 million dollars in 1958.

Lazzara predicts that the entire foundry industry will shift in the direction of investment casting as fast as it becomes able to install the required production facilities.

Reed-Prentice . . Worcester, Mass., will consolidate their operations into Package Machinery Co.'s new plant, at East Longmeadow, Mass., this spring. The company will utilize the larger facilities to expand manufacture of vacuum die-casting equipment. An unprecedented demand for cold chamber machines is predicted.

Morris P. Kirk & Son . . Los Angeles, subsidiary of National Lead Co., has announced development of a new high-strength zinc base alloy for metal forming dies. The dies will find principal use in the aircraft and automotive industries for dies and tools to produce sheet metal stampings. The alloy is said to reduce die weights 20 per cent while providing longer life.

■ For more information about this new alloy, circle F, page 7-8.

Institute of Scrap Iron & Steel Inc. . . Washington, D. C., reports that steel mills and foundries in the United States used less scrap to make new steel and castings in 1957 than in 1956, but demand from foreign countries was somewhat larger. Domestic mills and foundries consumed approximately 66.3 million tons of scrap dur-

◄ Circle No. 569, Page 7-8

ing 1957, about 8 per cent less than in 1956. The Institute foresees little 1958 change in scrap usage.

Archer-Daniels-Midland Co., Federal Foundry Supply Div. . . Cleveland, has established a new sales management organization to integrate the previous Foundry Products Div. of the company with the former Federal Foundry Supply Co. sales group. Production facilities, laboratories, technical service, and sales personnel of the former two groups have all been integrated into one division.

Davenport Machine and Foundry Co. . . Davenport, Iowa, has purchased the manufacturing and sales rights of the Hansberg core shooter, invented by F. Hansberg, of Italy.

Hansberg, center, and sales manager W. Geisler view machine's operation.

The core shooter is said to represent the most important improvement of core making machines since the invention of the core blower; and to have practically eliminated core blowers in Europe.

National Malleable & Steel Castings Co. . . Cleveland, has signed a contract to acquire the Grand Rapids Plating Co., and its subsidiary, Grand Rapids Die Casting Co., both of Grand Rapids, Mich. This brings the number of National's plants to eight, with total employment over 5000.

Bakelite Co., Div. Union Carbide Corp. . . New York, has announced that Cadillac Plastic & Chemical Co., Detroit has been made a distributor for Bakelite epoxy resins and hardeners. The new distributor will maintain a technical advisory service for epoxy users and dealers.

Somerville Iron Works . . Chattanooga, Tenn., has announced that "due to economic conditions beyond its control," the foundry is being closed.

dietrich's corner

by h. f. dietrich

The Apposable Thumb

About one million years ago a new animal began to roam the earth. It was distinct from other animals because it had an algebraic brain and an apposable thumb. For hundreds of thousands of years it devised ways and means of using the apposable thumb. For the last hundred years it has feverishly searched for methods that avoid the use of that thumb.

By inventing automatic, or pushbutton, gadget control, man is doing his best to use no more than his index finger. The number of things he can do without the use of a thumb is growing daily.

He can vote by machine, drive a car with pushbutton control, machine a casting, or charge a cupola using no more than one or two fingers.

Charging a cupola in the days before skip hoists and drop-bottom buckets was an interesting experience. A man had to be physically constituted for the job. To qualify, he had to throw a 140 pound pig to the far wall of the cupola while facing a 1700 F flame that showered hot chunks of breeze into his collar. By using a 2 x 12 plank on the charging door sill, he could charge anything that would go through the opening. Because the charging floor was directly above a belching slag hole, he had to endure a perpetual hotfoot while he inhaled more than his quota of carbon monoxide gas.

The materials charged, and the methods used to charge, made of metallurgy an art rather than a science.

Pig was sand cast. The size depended upon the ambition of the pig molder in the blast furnace shop. He dug holes in the floor that held anywhere from 70 to 108 pounds. This pig had to be charged around the walls of the cupola. Fused sand on the pig wore through leather gloves in one heat, provided you could keep the gloves that long. Usually, the gloves hooked on the flash that came with all pig and followed the pig into the furnace. You can't retrieve gloves from a hot stack. The rest of the heat had to be charged barehanded. Eventually, scar tissue and callouses made it difficult for a man to feel whether or not he was wearing gloves.

Coke was charged with a scoop, or a fork. The amount was a matter of experience and judgment and had to be varied from car to car because of variable quality.

Customer pressure forced quality castings. The foundry in turn put pressure on suppliers for more uniform products, and the blast furnace shops responded with mammoth receiving ladles and permanent molds.

The first permanent mold cast pig helped the men on the charging floor, but did little for the metallurgist. Weights of 70 to 80 pounds became uniform and smooth to a degree unknown in sand cast pig.

The section size of machine cast pig was larger than most scrap, therefore, metallurgical control was difficult. The large pig didn't melt with the rest of the charge. Further pressure from the foundry resulted in small pig of a size more nearly that of other melting material. Because the pig could be placed anywhere in the charge, mechanical charging became a fact.

Modern charging has become a matter of electronic control. Pig and scrap are loaded into a charging bucket by electromagnet, measured amounts of uniform coke are dumped from a batch hopper, and the bucket is dumped electrically while the charging crew stays far away from the inferno of the charging door. Even alloys are added from vibrating conveyors. The days of the cupola charging perfectionist are over.

More and more, man has used his algebraic brain to avoid the use of his thumb. The archaic hand of modern man has become obsolete.

Ford Marks Anniversary of V-8 Cast Block

■ Ford Motor Company made its 25,000,000th V-8 engine in 1957 although experts told Henry Ford a quarter century ago that the V-8 could never be mass-produced.

The Ford V-8 is in its silver anniversary year because the late Mr. Ford ignored words like "impossible" and "it can't be done." The company scheduled the 25,000,000th engine to be an Edsel V-8 produced in the Lima, O., plant.

December 7, 1931, Mr. Ford abruptly halted production of the four-cylinder Model B—successor to the Model A—and announced he would begin mass production of a car to be powered by a V-8 engine.

When he said he would do this by casting the engine block in one piece, many refused to believe that it could be done.

There was no way possible, it was said, to make a sand mold that would successfully cast an engine block with two banks of four cylinders set at right angles to each other, plus 16 valve sections and some 30 other openings, all in one massive chunk.

If Ford heard the clamor, he shunned it and went on to become the first to make rapid monoblock casting possible, and the first to mass produce the V-8 engine. In the intervening years, Ford Motor Company has made more V-8s than all the rest of the industry combined.

For the first 20 years or more, all V-8 engines produced by the company were built in the Rouge in Dearborn—the overwhelming majority of them for Ford cars. Today, V-8 engines for Ford passenger cars and trucks, Mercurys, Lincolns, Thunderbirds and Edsels are produced not only in the Rouge, but in two plants in Cleveland, O., and another in Lima.

In the decade between 1921 and 1931, Ford and his engineers had experimented with more than 200 different engines.

He had discovered what most engineers now agree on: that the four-cylinder engine was the most efficient of all, and that the ideal way to get efficiency plus more horsepower was to join two four-cylinder engines at right angles, to drive a short, rigid crankshaft.

As an engine design the V-8 was far from new.

The De Dion Bouton company in France had been making them since 1909. In 1931, any buyer with $4,000 or more in his pocket could have his choice of 13 different American automobiles with V-8 engines. They were the most powerful cars on the road. They were also the most expensive.

The cylinders were cast sometimes singly, sometimes in pairs, sometimes in groups of four, then bolted together in V-shaped alignment. The result was a fine, hand-made engine, but the process was slow and production costs were enormous.

If the V-8 Ford was to sell at around $550, as the company hoped, engines would have to pour out of the foundry in a steady stream just as their four-cylinder ancestors had done. This meant monoblock casting.

Even Ford's own engineers were appalled at the idea, and some of them simply folded their slide rules and faded quietly out of the picture.

But if Henry Ford ever once thought that a one-block casting of his V-8 engine was contrary to all reason, he never admitted it, even to himself.

"Anything that can be drawn up," he said, "can be cast."

In the old Edison laboratory at Greenfield Village, which the engineers called "Fort Myers," Mr. Ford and others drew sketches. They chalked them on a big blackboard, took pictures of them, changed the design and took more pictures, then swabbed the board clean and started over.

"Funny thing about that engine," one of the engineers said years later about the V-8. "The whole thing was designed out of Henry Ford's vest pocket. Just sketches he made."

In the foundry, however, life was taking on all the aspects of a nightmare.

Hot metal turned the sand to slag in the molds. Cores shifted out of position and sometimes burned up when the hot metal hit. Sand holes erupted through the walls of the castings. Blocks cracked and fell apart.

The great, new car with the V-8 engine had been promised to the public on April 1, 1932. As 1931 drew to a close, engineers and foundrymen were working around the clock, some of them virtually living in the foundry, in their frantic race against time.

It was March 9, with three weeks to go till deadline, when the first good V-8 block came out of the foundry.

Casting problems were overcome finally by the use of phenolic resin to bind the sand. Cores were wired and placed by machine rather than by hand. Problems of carburetion, timing, oil consumption, valve operation and a lot of others were solved, one after another.

The day came when they got six good engines. Before long, they were making hundreds. On April 1, 1932, nearly every dealer had at least one V-8 Ford on his showroom floor.

The first good V-8 that came out of the Rouge foundry that March 9, 1932, may still be seen in the Henry Ford Museum in Greenfield Village—a solid monument to the stubborn persistence of a man who insisted simply:

"Anything that can be drawn up can be cast."

ASTM Releases Supplement to Non-Ferrous Standards

■ American Society for Testing Materials has published the non-ferrous metals 1957 supplement to the 1955 Book of ASTM Standards. The supplement includes 56 standards covering copper and copper-base alloys; aluminum and aluminum-base alloys; magnesium and magnesium-base alloys; die-cast metals; corrosion tests and general methods of testing.

The complete book of standards is published every three years, and supplements are issued during each of the intervening years.

Build an idea file for plant improvements. Reader Service Cards, page 7-8 will bring more information . . .

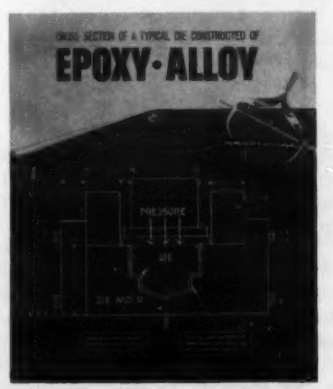
for the asking

Index to 1957 issues of Modern Castings available. Valuable cross-reference by subject, author, and company enables reader to find material quickly and with a minimum of effort. For your free copy circle No. 461, Reader Service Card, page 7-8.

Ductile iron catalog presents data on Silmag alloys for desulphurizing, nodularizing and inoculating. Compares cost with various magnesium additives. *Ohio Ferro Alloys Corp.*
Circle No. 462, Page 7-8

New wear-resistant steel for shot blasting equipment, plow and pug mill tips, chute liners and liners for sand handling equipment explained. New catalog shows diagrams and exact dimensions of wear parts manufactured. *Latrobe Steel Co.*
Circle No. 463, Page 7-8

Epoxy-alloy described in announcement that explains new composition extending benefits of plastic tooling.



Six case histories show excellent results in long production runs. Used for low-production draw dies; opens new tooling market. *Bakelite Co.*
Circle No. 464, Page 7-8

Ductile iron digest describes new metal as strong as carbon steel. Tensile strength up to 200,000 psi. Can be twisted and bent without cracking, as much as 30 per cent elongation. Charpy impact values range from 15-115. Booklet contains 24 case histories of strong, tough castings ranging from tiny levers to huge engine frames. *International Nickel Co.*
Circle No. 465, Page 7-8

Steel casting brochure lists three basic requirements for successful product design. Charts tell how you can take advantage of functional requirements, favorable cost, and low maintenance. *Steel Founders' Society of America.*
Circle No. 466, Page 7-8

High alumina refractories bulletin lists uses and applications. Circular also describes standard brick, special shapes and ramming mixes with detailed information on Ironton AL-70, 70 per cent alumina brick and Ironton HI-AL ramming mix. *Ironton Fire Brick Co.*
Circle No. 467, Page 7-8

Air setting binders, technical article, lists the advantages and disadvantages, equipment, temperature, decreased waiting time, core washing and baking, patching, and slicking. *Archer-Daniels-Midland Co.*
Circle No. 468, Page 7-8

CO_2 shell molding development reviewed. New process and advantages of being non-inflamable and non-gas forming is described. *Philadelphia Quartz Co.*
Circle No. 469, Page 7-8

Gamma radiography of castings detailed in 18-p manual covering cost, versatility, safety, portability, maintenance, and exposure time. *Nuclear Systems Div., Budd Co.*
Circle No. 470, Page 7-8

Machining manual, 22-pp, contains guide for machine feeds and speed, quantity-weight slide rule calculator, and other basic information. *Kaiser Aluminum & Chemical Sales, Inc.*
Circle No. 471, Page 7-8

Welders' vest pocket guide, 60-pp, describes and illustrates complete information on metals and electrodes, four essentials of proper welding pro-

cedures, types of joints, welding positions, explanation of A.W.S. classification numbers, and comparative index of electrodes. *Hobart Bros. Co.*
Circle No. 472, Page 7-8

Arc-welding process using inert-gas-shielded tungsten explained in 24-p catalog. Shows rapid joining of light gauges of hard-to-weld metals and alloys. This process which shields welds from atmospheric contamination includes a complete line of manual, semi-automatic, automatic, and accessory equipment. Process joins practically any metals or combinations of metals. *Air Reduction Sales Co. Div., Air Reduction Co.*
Circle No. 473, Page 7-8

Investment-cast-metals chart, offers reference material on ferrous base and non-ferrous alloys. Gives mechanical properties for metal—in as—cast or annealed state and in hardened condition. *Alloy Precision Casting Co.*
Circle No. 474, Page 7-8

Machining gray and nodular iron, 22-p booklet, covers machining properties of cast iron, cutting tools and machine tool requirements, economics of cutting speed versus tool wear, tool change and repair, and idle machine time. Informative performance data supplied on various types of grinders. *The Hamilton Foundry & Machine Co.*
Circle No. 475, Page 7-8

Lithium uses, present and future, summarized in monthly newsletter. Includes a review of new developments as well as current articles appearing in trade publications.

Circle number 476 on Reader Service Card, page 7-8 if you would like to receive free monthly newsletter. *American Lithium Institute, Inc.*

Carbonized wood flour, pocket-secretary data sheet. Lists advantages of product, packaging, price schedule, properties, and recommended uses. *American Colloid Co.*
Circle No. 477, Page 7-8

High temperature refractory materials technical data chart and refractory comparison chart for 8 materials includes chemical formula, true specific gravity, melting point, normal use temperature, thermal conductivity coefficient of linear expansion, specific heat, resistivity. Handy wall or notebook reference. *Zirconium Corp. of America.*
Circle No. 478, Page 7-8

Zinc and aluminum die casting monthly newsletter offered to foundrymen. Your name can be added to mailing list by circling No. 479 Reader Service Card, page 7-8. Additional copies

of any special interest can also be obtained. November issue covers progress of vacuum die casting method; metal markets; finishing die castings, and other informative material. *Lloyd Products, Inc.*

Tool room grinding of alloy, high-speed, and die-steels brochure, 24 pp, covers 22 areas in bonded abrasives field is designed to be a single source book on grinding for tool room men. Illustrative pictures and quick reference charts. *Carborundum Co.*
Circle No. 480, Page 7-8

Investment (lost wax) process evaluated in monthly newsletter. Successful use in metalcastings analyzed—cost versus production, tolerances. *The Metal Castings Advisor.*
Circle No. 481, Page 7-8

Foundry molding equipment catalog lists specifications and descriptions of flasks, wheelbarrows, carts, their types and uses. Illustrates flask clamps, pin wrenches, pins, hardened steel bushings. Has cutaway pictures, specifications tables, explanation of flask symbols. *Sterling Wheelbarrow Co.*
Circle No. 482, Page 7-8

Catalytic coating 8-p brochure describes wide range of IFCO industrial uses and product adaptability. Outstanding characteristics of coatings said to be: tremendous adhesion, durability and wear resistance; high immunity to humidity, moisture, and water; air-drying speed of 5-10 min. Protect castings from many kinds of corrosion. *Industrial Finishes Co.*
Circle No. 483, Page 7-8

Pump castings bulletin, 20 pp, discusses controlled structure of product, resultant structural combinations, resistance to wear, impact, erosion, pressure, corrosion. Evaluation tables, tabular summary of Meehanite physical properties are included. Valuable source of ideas for high-strength cast iron applications. *Meehanite Metal Corp.*
Circle No. 484, Page 7-8

Acid resistant ware catalog available. Covers polyethylene and nylon products not affected by concentrated acids, oxidizing agents, hydroxides and polar liquids. Technical properties of 64 products discussed in relation to uses in chemical laboratory. *General Scientific Equipment Co.*
Circle No. 513, Page 7-8

Stopper heads—helpful tips to foundrymen on care, handy storage, and elimination of damage outlined in this first of a series of brochures. New shipping container said to afford extra protection in transit and during storage thereby reducing warehousing and handling costs. *Joseph Dixon Crucible Co.*
Circle No. 485, Page 7-8

Lift truck design engineering discussed in booklet. Behind-the-scenes account of engineering principles involved in production of fork-lift trucks. Graphic presentation of new-type mast, one-piece frame, counterweight design, and fuel saving devices of truck. *Towmotor Corp.*
Circle No. 486, Page 7-8

Laboratory furnaces and other lab ware covered in 16-p brochure. Lists prices, description, chamber diameter and length. Temperatures 1250-2600F. Thermo-regulator for temperatures up to 2600 F, thermo-vac oven, high torque stirrer are among items shown. *Schaar Co.*
Circle No. 487, Page 7-8

Ferrous and non-ferrous cutting machines bulletin. Describes equipment including all standard cut-offs of 5 hp up to universals of 20 hp. Cut at practically any angle, on almost any shape casting. Compared to sawing or chipping operations, these machines are said to reduce cutting time from 50 to 90 per cent. *Tabor Mfg. Co.*
Circle No. 488, Page 7-8

Atomic energy review of industrial application of radioisotopes. Of special interest to foundrymen who have not as yet used industrial radioisotopes. Highlights uses, licensing requirements, and safety precautions. Covers industrial research, radiography, gaging, tracers, ionizers, polymerizers and radiators. *Machinery & Allied Products Institute.*
Circle No. 489, Page 7-8

Foundry flask catalog contains plan view of specially designed flasks of rigid and durable design. Wall-thickness 3/16- to 1/2-in. available with inward corrugation and reinforcing ribs. Twenty-two styles are illustrated by photos and line drawings. Also covered are bottom boards, core plates, squeeze plates, flat band upsets, and bushings. *American Foundry Flask Co.*
Circle No. 490, Page 7-8

Handy saw-blade selector wall chart for shop use offered. An aid to selection of proper saw blades for specific sawing jobs. Lists factors effecting cutting rate, tool life and finish. Lists recommended cutting rates for carbon steel and high-speed steel saw bands in relation to material work thickness, as well as saw pitch and lubricants to be used. *DoAll Co.*
Circle No. 491, Page 7-8

Vacuum calculator now available. Brochure covers revised version which is a handy-sized slide rule for deter-

mining pumping capacity needed to evacuate given volume to a specific vacuum in a given time or computing time required to reach a specific vacuum in given volume with pump whose capacity is known. Also displays vapor pressure of water at various temperatures and many other pertinent factors. *Vacuum Equipment Div., F. J. Stokes Corp.*
Circle No. 492, Page 7-8

Tumbling media vest-pocket reference describes current lines listing specifications, and prices. Tumbling barrel shown as high precision machine. Folder describes general applications for aluminum oxide tumbling pellets and rubber bonded media. *Electrominerals Div., Carborundum Co.*
Circle No. 493, Page 7-8

Stainless steel casting is the subject of 4-p brochure. Describes three new foundry methods—shell core, exothermic insert, and CO_2 hardened sand—combined to produce complex main body of fuel ignitor valve for jet engine which is made of high heat-resistant tool steel. *Cooper Alloy Corp.*
Circle No. 494, Page 7-8

Abrasive mounted wheels catalog has new index color tabbed for easy location of grinding action, wheel markings, grade, bond types, abrasive types, structure, grain size, spindles and treatment. Availability of mounted wheels set forth in chart-form, giving information at a glance. *Bay State Abrasive Products Co.*
Circle No. 495, Page 7-8

Ultrasonic test techniques outlined in booklet. Explains inexpensive technique (even without capital outlay) which reduces or eliminates waste by preventing machining of faulty materials, insuring casting quality. Included are ferrous and non-ferrous metals, plastics, ceramics, rubber and glass. Outlines company utilization of ultrasonic inspection at low cost. *Sperry Products, Inc.*
Circle No. 496, Page 7-8

Reference catalog, 16-pp, gives complete summary of products. Alphabetic listing of over 1500 products includes: alloys and metals; carbon products; chemical products; industrial gases and equipment; plastics; nuclear products; and consumer products. Shows sales offices by state and city, and trade marks. Handy guide in obtaining foundry needs. *Union Carbide Corp.*
Circle No. 497, Page 7-8

Compressed air processing brochure is designed to help foundrymen make better use of compressed air power. Discusses the worthwhile advantages gained in better and longer air equip-

ment performance with lower maintenance costs through simple processing. *C. A. Norgren Co.*
Circle No. 498, Page 7-8

Materials handling equipment catalog, 8 pp, presents various designs of boxes, hoppers, pallets that can be moved and stacked to save labor and space. Recommends "move it and stack it" techniques for peak efficiency. *Brummeler Steel Products Corp.*
Circle No. 499, Page 7-8

Materials handling system operated by "one man crew" presented in 8-p brochure. System adapted to receiving and shipping operations in metal-castings industry. One employee works alone serving as stripper, checker and leader. *Lewis-Shepard Products, Inc.*
Circle No. 500, Page 7-8

Weekly publication of news notes gives latest information on pneumatic dry sand reclamation. Covers units designed for low-cost installation; cost variations; output rate. *Beardsley & Piper Div., Pettibone Mulliken Corp.*
Circle No. 501, Page 7-8

Foundry equipment catalog, 58-pp, the result of almost half a century of constructive development in design of foundry flasks and accessories. Dimensional illustrations, specifications, charts and explanation of flask symbols given. *Sterling Wheelbarrow Co.*
Circle No. 502, Page 7-8

Pneumatic production equipment covered in 10-p bulletin. Grinders, sanders, drills, reamers, cutting tools specifications given. *Airetool Mfg. Co.*
Circle No. 503, Page 7-8

free films

■ Motion pictures and other visual aids based on foundry processes and supplies are also yours *for the asking.* These films are suggested for formal or informal training groups. The owners of films in this column will send booking request forms to MODERN CASTINGS readers who circle the appropriate number on the Reader Service card (page 7-8).

"Mechanical and Hydraulic Hand Lift Truck" is the title of 16-p brochure that tells what they are, how they operate, how to select, and how to use. Provides basic understanding of part played by hand-lift trucks in industrial materials handling systems. *Association of Lift Truck and Portable Elevator Manufacturers.*
Circle No. 504, Page 7-8

Hyster Hydraulic Backhoe, 16mm, audio-visual, color film runs 11-1/2 min. Presents D4 Backhoe as utility excavating machine for digging problems encountered in construction and maintenance work. Copies of the narration available for study before running film and for distribution to the audience. *Hyster So.*
Circle No. 505, Page 7-8

Pathway to Profits, 16 mm, color, 12 min film. Describes how in-the-floor type conveying systems for moving 4-wheel platform trucks can solve problems of handling foundry materials and reduce operating costs on terminals, docks, warehouses. Shows how they are used to convey large component parts through process and assembly operations. *Link-Belt Co.*
Circle No. 506, Page 7-8

Fiery Magic, 16mm, color, sound film. Title refers to blazing electric furnaces where coke and lime are combined to form calcium carbide. Consecutive steps in manufacture of carbide are demonstrated by animated flow chart. Industrial uses of acetylene portrayed. *National Carbide Co.*
Circle No. 507, Page 7-8

Ductile Cast Iron, 16mm, color, sound, 16 min. This film on spheroidal graphite cast iron portrays properties of this material in relation to specific applications. *Rothacker Inc.*
Circle No. 508, Page 7-8

Modern Materials Handling Methods, 16mm, black and white, 23 min. Covers various handling operations pertaining to boxcar loading and unloading, and warehousing; also the proper use of industrial trucks and tractors as outlined by Air Force engineers. *Industrial Truck Div., Clark Equipment Co.*
Circle No. 509, Page 7-8

This New World of Metals, 16mm, 20 min film. Film guides you through one of America's most recent pilot production facilities for the research, development and processing of new metals and alloys developed in the field of metallurgy. *Westinghouse Electric Corp.*
Circle No. 510, Page 7-8

Applications of R. F. Induction Heating, color, 16mm film, 15 min. Factual film shows advantages and success of RF heating when process is used to through heat, harden, anneal, solder or braze metals. Efficiency and varied application shown. *Westinghouse Electric Corp.*
Circle No. 511, Page 7-8

The Big Difference, 16mm, color, sound, 16 min film. Entertaining and educational film showing the actual development of testing a "Superior Engineered" casting. See testing, design and re-design of parts, and results. *Superior Steel & Malleable Castings Co.*
Circle No. 512, Page 7-8

TECHNICAL TALKS on tape

■ Tape recorded talks on 21 important facets of metalcasting technology are now available for sale. These 21 subjects have been selected by the editors of MODERN CASTINGS and are recommended as training aids for in-plant programs, for individual study, and for gatherings of technically-intent foundrymen.

All talks were recorded at National, Chapter and Regional meetings of the American Foundrymen's Society. Each presentation is complete, including the question and answer period. Any conventional tape recorder may be used.

Titles of the recordings and their sale prices follow. An order form is on the next page.

Producing Quality Castings (90 min)
by Nathan Levinsohn . . $7.50

Existing Processes and How to Improve Them (60 min)
by Harold H. Johnson . . $5.00

Discussion—Foundry Problems (46 min)
by Harry H. Kessler $4.50

Coke and its Relation to Cupola Operation (45 min)
by J. W. Randall and M. R. Gallo $4.50

Air Pollution Control for the San Francisco Bay Area (45 min)
by Benjamin Linsky . . . $4.50

Welding Steel Castings with Carbon Dioxide as a Shielding Agent (45 min)
by J. J. Chyle $4.50

Effect of Carbon and Manganese on Properties of Constructional Steels for Dynamic Loading (38 min)
by R. D. Engquest $4.25

Hydrogen as it Affects Steel Castings (45 min)
by A. E. Gross $4.50

Graphitization Theory and Mechanics, Effects of Chemistry and Melting Conditions on Overall Cycles. (70 min)
. . . . $7.25

modern castings

FOUNDRY FACTS NOTEBOOK

Green Sand Molding

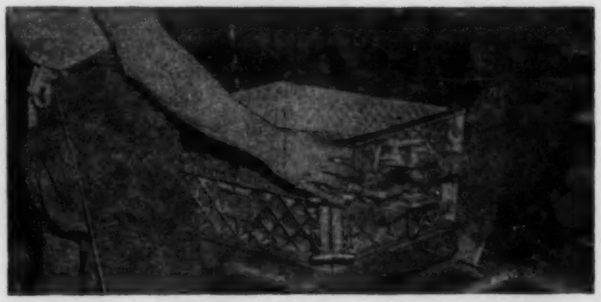
Use of Jolt-Squeeze Molding Machine

Foundry Facts Notebook is designed to bring you practical down-to-earth information about a variety of basic foundry operations. As the name implies, this page is prepared for easy removal and insertion into a notebook for handy future reference.—Editor.

The jolt-squeeze molding machine is well suited, because of its versatility, for foundries which produce castings of many different sizes and shapes. Such foundries may employ as many as 800 different patterns which must be changed quickly, regardless of size and weight, to achieve maximum savings in time and money. The production line must provide a steady flow of quality molds. Here is a picture sequence showing how jolt-squeeze molding is done.

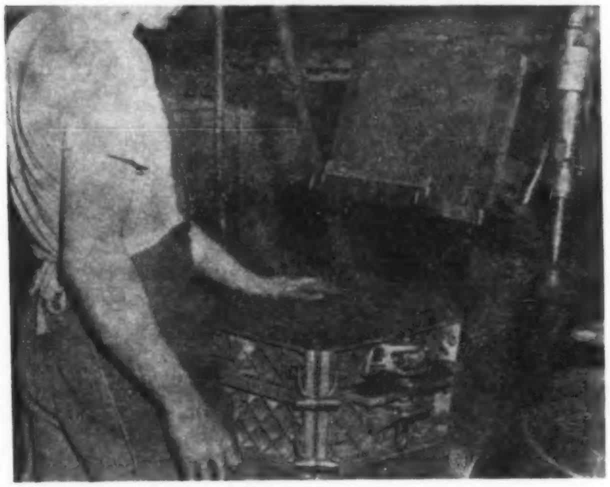
Overhead sand hopper (top) equipped with a vibrator feeds each station. Operator puts cope half of snap flask on jolt table of jolt-squeeze molding machine; match plate for cope is in the center of the picture . . .

. . . Operator places matchplate over cope half of flask. Drag half of flask (foreground) is placed . . .



. . . over matchplate and cope half of flask. Aligning pins on either side of drag fit into holes of matchplate and cope half of flask assuring perfect assembly . . .

Use of Jolt-Squeeze Molding Machine

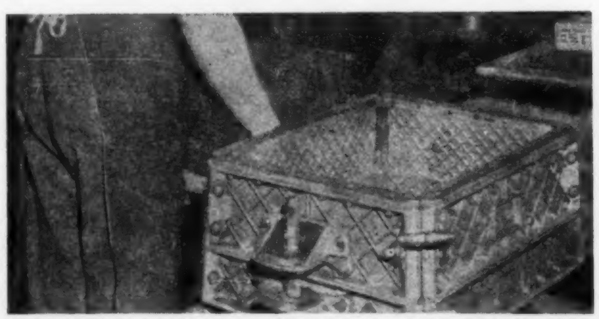


. . . Operator then fills drag half of flask with sand from overhead hopper. Valve is pushed with his knee causing the machine to jolt ram the drag . . .

. . . Wooden bottom board (visible under the flask) is then placed on top of drag before roll-over of entire mold. The operator fills cope with sand and mold is squeezed . . .

. . . Operator then lifts the cope flask and mold from the matchplate; next he strips the matchplate from the drag and inspects drag mold before inserting cores or chaplets if needed. Cope is replaced on drag . . .

. . . Hinges on the cope and drag are unlocked and flask removed from around mold. Operator then places mold on conveyor (left) for transporting to pouring area. Molds are jacketed and weighted before being poured.



■ Courtesy of Osborn Mfg. Co., Cleveland; pictures taken at New Idea, Inc., Coldwater, Ohio.

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let's get personal

Continued from page 119

W. R. Jennings . . has retired as foundry superintendent, John Deere Waterloo Tractor Works, Waterloo, Iowa. **S. E. Mapes** has been named general superintendent; **A. V. Schoville,** foundry superintendent; and **J. E. Stock,** superintendent of foundry methods and processes.

R. F. Foster . . has been made general foreman, Olney Foundry Div., Link Belt Co., Philadelphia.

Edward P. Sandbach . . has been named chief metallurgist for Mackintosh-Hemphill Div., E. W. Bliss Co.

E. P. Sandbach

He will head the metallurgical departments in the firm's Pittsburgh and Midland, Pa., plants.

George Smith . . is now general foreman, and **John Williams** assistant foreman at Florence Pipe Foundry & Machine Co., Florence, N. J.

J. F. Chamberlain . . formerly a partner of Engineered Sales Co., Summit, N. J., has been named vice-president of the company.

R. S. L. Andrews . . has been appointed executive engineer, Demmler Mfg. Co., Kewanee, Ill. He was formerly consultant to the firm.

M. H. Davidson . . has been appointed to position of development engineer for the Applied Research and Development Laboratory, Foundry Dept., General Electric Co., Schenectady, N. Y.

T. E. Ward . . has retired as president and general manager, Badger Malleable & Manufacturing Co., South Milwaukee, Wis. His son, **J. E. Ward,** was named executive vice-president to head the company.

Mario Olivo . . Italian foundry technologist, has been named Member

of Honor of the French Foundrymen's Association.

Alten Foundry & Machine Works, Inc., Lancaster, Ohio reports that **L. C. Gruber** has been made manager of the firm's Plant No. 2. He was formerly plant superintendent with Weinman Pump Mfg. Co., Columbus, Ohio.

A. Dorfmueller, Jr. . . has been made general sales manager, Federal Foundry Supply Div., Archer-Daniels-Midland Co., Cleveland. He is vice-chairman of the AFS Mold Service Committee, and past treasurer, AFS Canton District Chapter. Additional promotions include: **J M.. Sweeney** to manager, Foundry Facings Div.; and **J. J. Schwalm** to eastern sales manager. Sales and service activities in the Denver area will be handled by **A. H. Patten**, Patten Engineering Co., Denver, Colo.

A. Dorfmueller, Jr.

John W. McCue . . is now field engineer at the Indianapolis district office, Norton Co., Worcester, Mass. He has served with the company as an abrasive engineer since 1951.

Dominion Engineering Works Ltd., Montreal, Que., reports that **J. McCallum** is the new superintendent, steel foundry.

Rex Precision Products, Inc., Culver City, Calif., reports that **L. B. Howerton** has been elected president of the firm; and **Geza Demeter,** vice-president.

Douglas L. Warner . . has been promoted to sales manager of the Foundry Div., Berlin Chapman Co., Berlin, Wis. He has been associated with the firm for over 10 years.

Ray Feree . . formerly vice-president of Pittsburgh Metals Purifying Co., Pittsburgh, Pa., has been elected president of the company.

the SHAPE of things

safety, hygiene, air pollution

by Herbert J. Weber

Would You Trust Your Life To A Sign, A Packing Crate Or A Red Rag? Some People Do!

Here are some reports I have received that should make us put an end to this kind of stuff.

1) Maintenance man shut off main switch and began repairs on power conveyor. A fellow workman intending to start up shakeout machine, turned on conveyor switch mistaken for shakeout switch. Maintenance man's arm was torn off at the shoulder.
2) Maintenance man entered sand muller to repair plows. Fellow employee unaware of repair work going on, started up muller. Maintenance man died two days later from injuries sustained.
3) Maintenance man repairing bucket on bucket elevator was crushed to death when fellow employee accidentally started up elevator.

Every one of these accidents occurred because the maintenance man failed to *lock out* the main electrical control switch. Even worse was the

method suggested to prevent a recurrence of accident No. 1. "In the future all switches must be properly identified so employees will not accidentally turn on the wrong switch."

Signs affixed to switches warning that men are working on power equipment will not prevent accidental closing of electrical circuits. I have found warning signs fallen to the floor and when I asked on what switch they belonged was told, "On one of those near the door." I have found packing crates thrown over a switch box or a piece of red rag tied to the switch handle, presumably as a safety procedure . . . . and about as safe as giving a child a loaded gun but with strict instructions not to pull the trigger.

Here's what the AFS Safety Manual says:

"Whenever it is necessary to make repairs on motors, electrical equipment or machines controlled by motors, the circuit should be opened at the switch box. The switch box should be padlocked in an open position and a work-description tag affixed, including the name of the man performing the repair work."

"Various techniques of control may be employed but the basic principle or need of each employee placing his personal lock on the switch when he starts his phase of the work on the equipment should be *mandatory*."

If a second man is working on the same system, he should also lock out the switch with his own lock even though the first man has already done so.

What if a man loses his key; should another be made from the duplicate kept in the office? No! Because the lost key may be found by another employee who may intentionally or accidentally use it to open a locked out circuit. The lock should either be destroyed or the tumblers changed.

Cheap locks which can be opened with a fingernail file or by tapping should never be used.

Employees should not be allowed to take safety locks and keys out of the plant, because of the possibility of their having duplicates made. All locks and keys should be turned in to a designated person at the end of each shift.

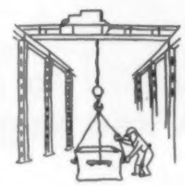
Locks opened by dial combination should be recalled periodically and re-issued to a different group of employees. Experience has shown that men working close together for some time inadvertently or purposely learn their partners' dial combination. When this happens, the protection of the lock is lost.

Remember, where power machinery is concerned, procedures must not only be foolproof . . . . they must be damn—foolproof.

I think it's trying to tell us something.

questions and answers

Misery loves company so why not share your castings problems with us? Modern Castings invites you to stump the experts with tales of gremlins that are haunting your scrap piles. If any of you readers have better answers to the questions below, write the editor.

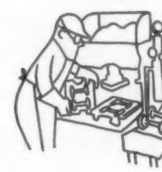


Q. About 400 ft from our cupola another plant has a parking lot for its employee's cars. This company recently complained that the finish on automobiles in this lot was being damaged by emission from our cupola. Is this possible?—M.L.M.

A. Yes, it is quite possible. The damage to the finish of the cars is due to the action of sulphuric and carbonic acids and iron oxide which are products of combustion from the cupola. The corrosive action on the body finish is more pronounced on humid days.

Q. As the result of many years experience in green sand molding we have a pretty good idea what sieve distribution is best for our floor work. We want to experiment a little with shell molding and guess that our green sand practices should be thrown out the window. What is your sand recommendation for shell molding? J.H.J.

A. The general trend is to coarser sand with 50-60 AFS Fineness Number in most common use. The sand should be washed and dried and have a distribution over at least three and preferably four screens. Material finer than 270 mesh and the pan material should be less than 15 per cent. Recent experiments with a 50-50 blend of silica and bank sands appears promising.



Q. Oversimplification of foundry techniques is often the root of many of our troubles. In a recent discussion about degassing copper base alloys, one of the foundrymen said all you had to do was flush the metal with nitrogen. I rather guess there is a right and wrong way to do this. How about outlining the right way to carry out this practice?—J.M.V.

A. For de-gassing one needs a cylinder of dry nitrogen, regulator flow meter, hose, a section of ½-in. iron pipe, and a graphite tube with a piece of porous graphite threaded on one end. The tube is fastened to the pipe to serve as a handle during de-gassing. Nitrogen flow rate of approximately 22 cu ft per hr is satisfactory for a crucible containing about 150 lb of metal. Quantity consumed is in the order of 25 cu ft per ton of metal. This figure will vary depending on the amount of gas in the molten metal, the degree of removal required, and the efficiency of the flushing action.

Q. We realize that a lot of our casting costs are coming from old fashioned manual handling of foundry materials. Like so many foundries that have grown like "Topsy" it would require a major remodeling to install floor level sand handling equipment. I understand that there is a sand distribution system that uses compressed air to push sand through overhead pipes. Would you mind telling me how this works?—S.P.

A. Pneumatic handling systems for sand operate essentially as follows: The sand is gravity or conveyor fed into a weigh-hopper from which it flows through an opening in the top of a pressure vessel. When the vessel is filled, the opening in the top is sealed by closing an electric or pneumatic gate valve. Compressed air from an air reserve tank is introduced into the sealed chamber to aerate or fluidize the sand. Air pressure is then utilized to carry the material through a system of pipes to any work station in the foundry where it is discharged into storage hoppers.

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2. Wants to grow with two young men in developing a well-established business into an outstanding foundry.

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Positions Wanted

INDUSTRIAL ENGINEER—33 year old graduate of General Motors Institute cooperative engineering program with 13 years experience in metal casting field, including automotive gray iron, university instructing, technical writing, pit molding job shop, will consider any position related to the foundry industry that offers opportunity as well as challenge. For resume, write **Box E-11, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

GRAY IRON METALLURGIST available. 19 years in jobbing, heavy machinery, automotive and powered metal shops. Experienced in metal, sand, and castings control. Illinois Tech trained. Will relocate. Salary open. Age 46. **Box No. E-13, Modern CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

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Widespread organization of international reputation seeks competent, metallurgically trained man experienced in cast metals and general engineering for responsible position as Technical Assistant. Will be charged with development of research projects, coordination of broad technical program and relations with engineers and technicians. Progressive organization, excellent opportunity advancement. Some travel. Write full details, personal background and qualifications, compensation required. Replies confidential. **Box E-14, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

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PERKINS SIGMA BLACK MIXER WANTED. 100 gallon working capacity. Must be in good condition. Reply to: **Box E-12, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

For Sale

ELECTRIC ARC FURNACES FOR SALE Two—2000 lb side-charge furnaces complete with transformers, extra tops and electrodes. Low price for quick sale. **FRED H. WUETIG, 7445 South Chicago Ave., Chicago 19, Illinois. HYde Park 8-7470.**

When you are in the market for steel containers for shipping your products, we have them in sizes running from 15, 20, 24, 30 and 55-gal. Open Head, reconditioned, washed, and painted all black at reasonable prices, delivered your city in lots of 50 to 100. We also purchase empty 30 to 55 gallon core oil, lubricating oil and grease drums. Please advise how many you have so we can arrange to quote you prices f.o.b. your city. **NORTHWESTERN BARREL CO., 3111 Fifth Ave., South Milwaukee, Wis.**

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Floor pouring equipment, 250 lb. ladles on overhead rails; also track weighing Toledo Scale; all in good condition.
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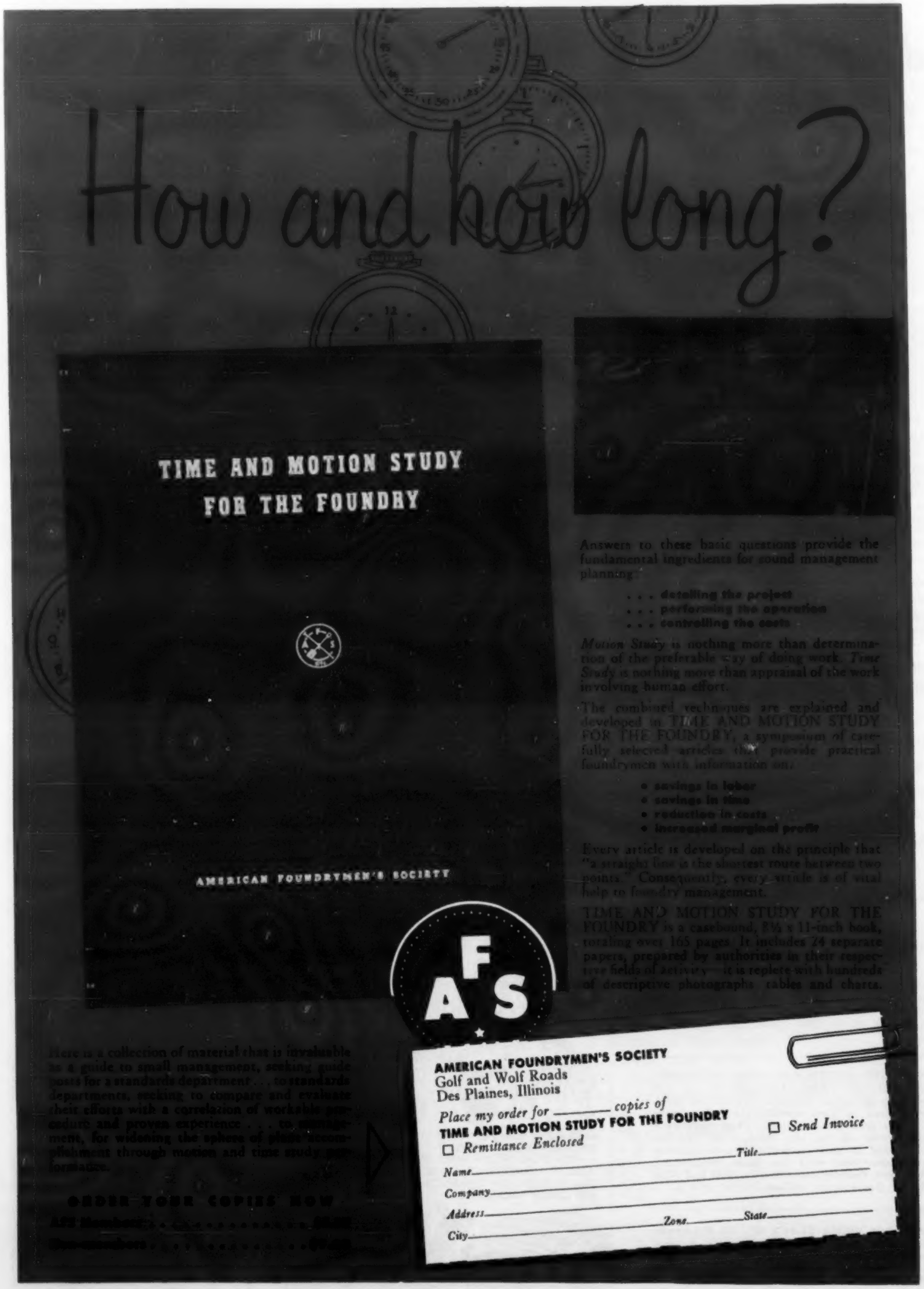
casting through the ages



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Czechs Hardening Molds in Molding Machines with CO_2

■ Foundries in Czechoslovakia are employing CO_2 to produce chemically hardened flaskless molds on standard molding machines. Use of the new adaptation is said to make possible the mechanization and, eventually, automation of flaskless mold and core production.

A Czechoslovak Research Institute for Materials and Technology booklet, *"Progressive Methods in the Foundry,"* describes how the new system works. A patternplate with an auxiliary box is mounted on a frame which holds the pressure plate. The patternplate contains a slit which lines up with a similar opening beneath the patternplate through which CO_2 is introduced.

After the mold is squeezed, it is hardened with CO_2, the pressure plate returned to its original position, and the mold ejected from the device.

These molds are reported to produce castings with higher dimensional accuracy; molding sand consumption is reduced 30-50 per cent; operator fatigue is lessened; and labor-saving, coupled with higher output per unit area of working space, has resulted in a higher casting yield and increased profits.

modern castings

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